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DEPARTMENT OF AGRICULTURE.

SPECIAL REPORT.

REPORT

ON

JUTE CULTURE,

AND THE

IMPORTANCE OF THE INDUSTRY.

UNIV. OF CALIFORNIA

By PROF. S. WATERHOUSE,
SAINT LOUIS, MO.

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JUTE CULTURE.

By Prof. S. Waterhouse,
Washington University, Saint Louis, Mo.

The recommendations of the Department of Agriculture first attracted my attention to this fiber, and the personal observations of a visit to India have only confirmed my sense of its national importance.

Jute has been cultivated in India for hundreds of years, but it is only within the last half century that it has entered largely into the commerce and industries of foreign nations. In the culture of jute, a warm, humid climate is essential to success; but the physical characteristics of the soils in which the plant flourishes greatly vary. It thrives with an almost equal luxuriance upon highlands or alluvial bottoms. It will grow upon comparatively dry uplands or in flooded valleys. But it prefers a high, moist, sandy loam. Alluvial mold in which there is a liberal admixture of sand is favorable to its growth, but a very dry or a very sandy soil is not adapted to this tillage.

The land intended for this crop is usually broken up in the fall. With unwearied industry, the natives plow the land over and over again—in some instances as many as twenty times—until the soil has been thoroughly pulverized, deeply exposed to sun and air, and richly manured. The seed is sown broadcast, from 20 to 30 pounds to the acre.

The time of sowing varies with the conditions of soil and climate. In the northeastern provinces of Bengal, where nearly all of the jute of India is raised, the seed is sown in February, March, and April. In the vicinity of Calcutta the seed is often planted as late as July. Sometimes two crops are raised in a season, but this is too exhausting to the soil. After the jute has come up, it is carefully thinned and then left, without much further tillage, to ripen. It matures in twelve or fifteen weeks. The plant sometimes grows to the height of 20 feet, but its average height is 10 or 12 feet, and the diameter of the butts varies from half an inch to an inch and a half. One variety which is extensively cultivated has a smooth white bark and wide-spreading branches. In the northern provinces of Bengal the average yield is from 2,000 to 3,000 pounds an acre; in the neighborhood of Calcutta it is from 500 to 1,000 pounds. In the north of the Bengal Presidency the quantity of seed raised per acre is 1,000 or 1,100 pounds; in the south it is 1,400 or 1,500 pounds. The jute is cut while the plant is in flower, because the fiber is then more glossy and less woody. The seed ripens one month

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after flowerage, and the fiber has then become so woody as to lose much of its commercial value. After cutting, the jute is usually kept two or three days, till the leaves fall off, and then it is immersed in water. The period of submersion varies, according to the temperature and character of the water, from three or four days to a month. The methods of steeping practiced by the natives are various. The fiber prepared in clear running water is strong, white, and glossy; the process, however, lasts for several weeks. But when the jute is soaked in stagnant water, although the disintegration is usually effected within ten days, yet the fiber is apt to be weaker and more discolored. But in either case the action of the water is to loosen the fibrous bark from the woody stalk. The natives test the jute from day to day, and when they find that the bark is ready for removal, they enter the water and withdraw the stems by a succession of jerks. Their reason for effecting this separation in the water is that the soft and even pressure of the fluid prevents the rupture of the fibers. After its removal the inner bark is stripped of its rind, freed from all woody adhesions, thoroughly washed, and immediately dried. It then readily separates into minute fibers, and is ready for the market or for domestic spinning.

In the provinces where jute is raised the distaff is in every hovel. The Mohammedans, deterred by some religious scruple, restrict themselves to the manufacture of cotton; but all Hindoos of the industrial classes, robust men, in the intervals of other employments; children, too young for severer tasks; the aged, too infirm for hard work; invalids, incapable of active exertion; and even the despised Hindoo widow, whose social degradation and misery powerfully appeal to the sympathies of Christendom for relief, engage in the spinning and weaving of jute. The manufacture of this staple, utilizing the leisure hours of the strong and dexterous handicraft of the weak, affords occupation to the myriads; but wages are so extremely low and the competition of industries so limited, that jute-yarn and gunny-cloth can be purchased almost as cheaply as an equal weight of the crude material. No portion of this substance is wasted. The leaves and ashes are used for manure, the stalks for baskets and fuel, the seed for oil and oil-cake, the roots for fuel and paper, and the silky floss which escapes from the fibers in the process of manufacture is wrought into hats.

Till recently the government of India has never fostered the cultivation of jute; but without its patronage this industry has, within the last half century, risen to a world-wide importance. In 1828 the total foreign sale of jute was less than 40,000 pounds, worth $300. Now, Calcutta, which is the great point of distribution, exports immense quantities of this staple to Bombay, Madras, Ceylon, Burmah, Singapore, Penang, Java, Australia, Brazil, the west coast of South America, France, Great Britain, and the United States. Only about one-fourth of the crop is reserved for domestic consumption. According to the fashion of the different countries, pepper, coffee, sugar, rice, cotton, soda, lime, the

matte and regulus of the precious metals, and many other articles of commerce, go to market in a dress made of gunny-cloth.

The statistics of the development of the jute-culture in India are impressive and suggestive. In 1862, India exported 10,000,000 pounds of fiber and rope and 300,000,000 yards of gunny-cloth. In 1863, Great Britain employed more than 30,000 spindles in spinning 80,000,000 pounds of Indian jute. Recently this staple has arisen to the dignity of the fourth place in the exports of India; only cotton, opium, and rice exceed it in commercial importance. Some of the Indian factories are immense. There is an establishment at Barnagpoor, near Calcutta, which employs more than 4,500 workmen, and annually manufactures more than 30,000,000 pounds of jute. In 1872, the total exportation of Indian jute was 700,000,000 pounds, of which Great Britain received upward of 395,000,000 pounds. In the same year more than 900,000 acres were devoted to the cultivation of jute in India; and in the thirteen provinces in which jute is principally raised, out of a population of 15,725,000, more than 1,350,000 were wholly or partially engaged in this occupation. These figures conclusively show the vast magnitude and importance of this industry to India. Other statistics will illustrate the value of this staple to an exclusively manufacturing community.

Nearly half a century ago some sagacious Scotchmen engaged in the manufacture of jute. Their humble experiment has developed into a success that has enriched Scotland and promoted the commerce of the world.

At first many difficulties arrested their progress. Much of the fiber was discolored by the tannic acid of the bark, through improper methods of preparation; and it was only after years of persistent effort that a successful process of bleaching was discovered.

Again, the fiber stubbornly resisted the action of dye-stuffs, and over this difficulty chemical science has yet only partially triumphed. Jute can now be dyed, but the colors are not fast. Still the variety of tints now imparted to jute permits it to be combined with other materials in cheap imitation of many valuable fabrics.

Jute is mixed with cotton, linen, and silk. It is a material part of twilled stair-carpeting and low-priced broadcloth. In combination with other textiles, it imitates the gloss of Irish linen, the luster of French silk, the beauty of Turkish rugs, and the splendor of Axminster, Kidderminster, Brussels, and Venetian carpets. Single or mixed, it enters into the manufacture of a thousand articles of commerce. In 1872, there were in Dundee about one hundred jute-mills, employing upward of 20,000 workmen, and manufacturing more than 180,000,000 pounds of jute annually. In the same year nearly 50,000,000 gunny bags—most of which were made in Dundee—were exported from Great Britain. Of the 300,000,000 pounds of jute that were manufactured in the United Kingdom in 1876, 200,000,000 pounds were woven in the mills of Dundee. The annual value of the flax, hemp, and jute manufactured in

was handled in bulk by elevators, barges, canal-boats, railroads, and steamships; but before it could be brought from the various points of production to these facilities of transportation it had to be inclosed in bags. If it were necessary to renew these bags every year, it would now cost the United States $100,000,000 annually for its grain, pulse, and potato sacks. This calculation is based upon the assumption that all the bags are made of jute. If the material were cotton, flax, or hemp, the expense would be still greater. But as the sacks last several years, the annual cost is not probably one-fifth of the above aggregate. In 1876, the cotton crop of the United States was about 4,500,000 bales, and at the ruling rates the cost of the gunny-cloth in which this cotton was sent to market was not less than $3,900,000.

Unlike the grain-sacks, the jute baling cannot be used a second time, and therefore a wholly fresh supply is necessary every year. Our native production of fibers is greatly inadequate to meet the demand. In 1868, the United States paid $23,000,000 for imported flax, hemp, and jute. In 1870, the cost of imported fibers was more than $30,000,000 in gold. The quantity of jute alone imported in 1870 was upward of 19,000,000 pounds. Yet these figures, although large, but imperfectly indicate the demand which there would be for jute if it were a domestic production. The cheaper fiber would, of course, be substituted for the more costly wherever it was possible, and accordingly jute, in consequence of its comparative inexpensiveness, would supplant hemp and flax in the manufacture of carpets and many other fabrics. For bagging and cotton-baling, jute has already almost entirely superseded the use of the other fibers. But possibly it will be found better, in order more fully to meet the varying needs of commerce, to interweave jute with cotton, flax, and hemp; and in that event the introduction of jute, instead of depressing, would stimulate the culture of these fibers. But the vast need of our country for grain-sacks, cotton-bale covers, and a cheap warp for a woof of other textile materials will create a correspondingly vast demand for home-grown jute. It will indicate a lack of southern enterprise if American jute does not yet rise to a textile importance second only to that of American cotton.

Heretofore the agriculture of the South has been restricted to the production of a very few staples. This narrow limitation of southern industry is an essentially false policy. The South has made the grave mistake of confining its activities almost exclusively to one pursuit. But no country can realize its highest possibilities of material greatness by following a single employment. The urgent need of the South today is a wide range of industries. It ought to superadd manufactures to a larger variety of agricultural productions. Then the competition of the different occupations would impart activity to business, give more employment to labor, create better local markets, raise the price of agricultural and manufactured products, increasing the profits of workmen,

planters, and manufacturers, and promote the well-being of the entire community.

The introduction of the growth and manufacture of jute presents a new opportunity for diversifying the industries of the Southern States. If the experiments which have been already tried in the South are a safe guide, then the profits of jute culture would amply reward the American planter.

According to the estimates of practical experience, jute-butts can be produced in the United States for 3 cents a pound in currency, and the fine fiber for 8 cents. The average price of Indian butts in this country is 3 or 4 cents a pound in gold, and the fine yarn is worth 8 or 10 cents a pound in gold. Nor is the difference between the cost of Indian and American jute the only source of profit.

There is a relative economy in the cultivation of this plant. According to southern testimony, it is four times as productive as cotton or flax, while at the same time it takes not more than one-tenth as much labor to raise it. In the manufacture of hemp and flax there is a loss of 15 or 20 per cent. of the material, while the loss in working jute is only about 9 per cent. In our markets jute-bags are worth from ¼ to ½ a cent a yard more than flax-bags. Hemp rots much quicker than jute does. The superior cheapness and durability of jute are rapidly displacing flax and hemp in low-priced manufactures.

There are also important incidental advantages of this tillage. The vigorous, luxuriant growth of the jute almost exterminates weeds from the soil in which it is sown, while the bitterness of its juice repels the attacks of insects. It has been found that cotton-fields surrounded by a belt of jute were exempt from the depredations of the caterpillar, while unprotected fields in the same neighborhood suffered from its ravages.

The profits of the domestic manufacture of jute are not unworthy of the attention of capitalists. Eighteen hundred and seventy was a year of exceptionally high prices. In that year the profit on the home manufacture of 19,000,000 pounds of jute was more than $2,000,000. Of jute fiber, butts, and rejections,* the total consumption in the United States in the last three years was over 300,000,000 pounds. At present, the average cost of jute-butts, delivered in Saint Louis, is 3 or 3½ cents, gold, per pound, and the ruling rate of the jute-baling manufactured in this city is now 12½ cents a yard in currency. From these data practical men will be able to form just estimates of the costs and profits of this manufacture. Imported gunny-cloth, generally of an inferior quality, now commands an average price of 9 or 10 cents a yard in currency;

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*These are technical terms. In the language of trade, "jute-butts" are sections, 12 or 15 inches in length, of the lower end of the plant. These coarser portions are made into heavy baling and bagging. The "fiber" is the long silky yarn, which is woven into finer fabrics; and the "rejections" are parts of the "fiber," which, in consequence of being stained, tangled, or woody, are unfit for delicate manufactures. "Rejections" are commonly worked up with the butts.

but domestic bagging, although somewhat more expensive, is, in consequence of its better quality and make, usually preferred. The home manufacture of jute-baling has already become an important industry. In 1876 the mills of Saint Louis alone manufactured 6,000,000 yards of jute-bagging. The domestic growth of jute would not only benefit the producers and manufacturers, but it would also impart prosperity to other industries. It would afford an inexhaustible supply of cheap material to the paper-makers. The root-fiber and other refuse portions of the plant, and the worn-out baling, sacks, and carpets, can now be converted into a smooth, strong, white paper. During the last five years about 170,000,000 pounds of jute were made into paper in the United States. The newspapers of the United States ought actively to promote an undertaking the success of which would so greatly redound to their own advantage.

It is a costly improvidence to pay other nations for staples and products which we can raise and manufacture as cheaply as they can. For all imported jute fabrics we are now paying the cost of production in India, the freight to England, the expense of manufacture, the transportation to the United States, and the commissions of all the factors and insurance agents through whose hands the goods have passed. Millions of dollars are now annually paid to foreigners for labors that ought to be performed by Americans. We are heedless of the lessons of public economy. A diversity of employments and an industrial independence of other countries will most efficiently promote the welfare of our own people. It is the true policy of the United States to introduce and naturalize the industries of the Old World and to foster the common wealth of the nation by paying to American handicraft the millions which are now the rich reward of European skill. The English government finds it very difficult to introduce improved machinery or scientific methods into the agriculture of India. The inert masses resist innovation with a conservatism born of centuries of stagnation. The traditional implements and processes of an earlier age are still used in the tillage of India. The plows and harrows and the machines for spinning and weaving are of the rudest description. The natives are too poor to buy improved tools and too ignorant to use the better methods. They have not analyzed their soils, ascertained the best succession of crops, tested the different systems of fertilization, or improved their primitive processes of preparing and manufacturing their staples. In fine, their labor is unintelligent, and therefore ineffective and unthrifty.

An industial comparison of our Southern States with India greatly encourages our hopes of success in this new industry. The labor of the South is far more intelligent than that of India, and it is constantly under skillful guidance. The southern planters will not follow an antediluvian style of agriculture. In India the best soil is usually devoted to raising jute for the market, and the poorer land is left for the pro-

duction of jute-seed. The natural consequence of this course is the deterioration of the seed. In the United States, on the contrary, a portion of the best land has been reserved for seed, and the result is a signal improvement in the quality of the seed. American jute-seed is one-sixth heavier than that of India. The broadcast sowing of Bengal is uneven and wasteful. Our patent drills, saving 10 or 15 pounds of seed to the acre, do the work with far greater rapidity and equality of distribution. The efficiency of our agricultural machinery will more than neutralize the seeming advantage which India possesses in the cheapness of its manual labor. It would take tens or hundreds of Indian hands to do the work of one American machine.

It will be strange indeed if the mechanical ingenuity which in some departments of manufacture has triumphed over the cheap skilled labor of Europe and enabled the United States profitably to export to the great centers of industrial art watches, cutlery, agricultural implements, coarse domestics, and some finer fabrics, cannot win a far greater victory over the unskilled hand-labor of India. It is high time for a general introduction of the culture of jute in our Southern States. Every step in the progress of naturalization should be attended by intelligent experiment. Tests of every kind of soil and treatment will result in better seeds, a larger yield, a rotation of crops that will be least exhausting to the soil, machines for the cheap and rapid removal of the bark of the plant, and processes of steeping that will separate the fiber without destroying its strength, color, or gloss. Then the new enterprise, giving employment to home labor and activity to domestic capital, will quicken the revival of our languishing industries, aid the South in regaining its material prosperity, and enrich the nation by the economy of millions which have heretofore been paid to foreign lands.

The foregoing article on "jute culture" appeared in the Annual Report of this Department for the year 1876. The industry is regarded as one of sufficient importance to warrant the republication of this paper in connection with a more recent treatise on the rapid expansion of the industry, from the pen of the same writer. The article is as follows:

EXPANSION OF THE JUTE INDUSTRY.

Hon. GEORGE B. LORING,

Commissioner of Agriculture:

SIR: Your proposal to republish my article on jute, with such supplementary observations as later experience suggests, was as unexpected as it is gratifying. The tender of my cordial acknowledgments for so distinguished a favor is accompanied with an earnest hope that this re-

print will not be wholly ineffective in promoting the development of an industry whose productive value may yet rival the economic importance of cotton.

It is now six years since the foregoing article on jute was originally published.

It may be instructive to glance at the surprising changes which have taken place in this brief period.

EXPANSION OF THE JUTE TRADE.

In 1878 the writer visited Dundee. The city presents an impressive spectacle of manufacturing greatness. The massive walls which surround the jute factories resemble the ramparts of extensive fortifications. The streets are shaded with a forest of lofty chimneys. Throughout the city there are on all sides conspicuous proofs of the great prosperity which a single industry has created.

Of late the jute mills of India have been dangerous competitors. English intelligence employing the cheap labor of Bengal has obtained control of adjacent markets. Formerly most of the jute goods which the far east consumed were manufactured in Dundee, but now the demands of the Oriental trade are supplied by the factories of India.

In the report of Consul Winter there is a tabulated statement of the number of gunny-bags exported from Calcutta from January 1 to August 31, 1881. In order to show how extensively this element of eastern commerce has been diverted from Scotland, some of these statistics are reproduced; but only the largest aggregates, quoted with the inexactness of round numbers, are here given. This partial table of the jute bags exported from Calcutta is as follows:

Destination:	Number.
South Africa	1,100,000
Australia, New Zealand, &c	3,000,000
Hong-Kong and San Francisco	17,750,000
Burmah, Straits and coast ports	25,340,000

But notwithstanding this vast loss of patronage, the manufacturers of Dundee have been steadily extending their business; though the number of factories remains about the same, their capacity of production has been materially enlarged; more than 30,000 hands are now employed in the jute mills of Dundee. In consequence of the ever-widening range of uses to which the fiber is applied, the consumption of jute is increasing all over the world.

The consular report above cited states that, with the single exception of Russia, jute factories have been established in every country of Europe. But in 1879 the exportations of jute to Great Britain, France, and the United States amounted to more than 730,000,000 pounds. If the consumption of three countries reached this aggregate, it would presumably be safe to conclude that the total exports to all lands are now not less than 800,000,000 pounds.

But India itself manufactures about 200,000,000 pounds. Late estimates place the present annual production of Indian jute at from 1,000,000,000 to 1,200,000,000 pounds. In the absence of recent statistics, it is impossible to ascertain the exact amount; probably these estimates are too high.

Ten years ago intelligent observers foresaw the present greatness of the jute industry. In 1872 Mr. George Burnet, of Scotland, visited India and examined the sources of supply. He says:

Believing, as we do, that the jute trade is the most expansive of any trade now in existence, and that within the space of the coming ten or fifteen years in India, Great Britain, America, and the continent, five or six millions of bales may be required annually, we see no reason to doubt that Bengal and British Burmah can easily and without displacing any other article of necessary consumption produce all that the growing trade requires. It is very apparent, however, that the present mode of growing and treatment and preparation is very rude and faulty. It is very difficult to introduce improvements amongst a class so widely scattered, having such small holdings as the ryots have and will continue to have.

Again, in 1873, he writes:

The trade in jute is one of the most expansive in the world. During the last quarter of a century it has progressed steadily and rapidly, until in the year 1866 the exports of jute, together with jute rejections and cuttings, reached 638,908 bales, while in 1871 it amounted to 1,644,311 bales. Last crop exceeds that in quantity, and it will all be required.

At the present time jute goods cannot be produced fast enough to meet the demand. Mills and factories are being increased in Great Britain and India, and are also being erected in Australia, America, and the continent of Europe. At the end of the coming decade the wants of the whole trade will likely reach four to five millions of bales annually.

Though Mr. Burnet's expectations were somewhat too sanguine, his prediction of a vast expansion of the jute trade evinced no lack of forecast.

The agricultural development of the United States in the last half dozen years has been marvelous. Our cotton crop is now 6,750,000 bales, and the total yield of cereals is 2,700,000,000 bushels.*

The production of vegetables which are carried to market in sacks is almost illimitable. The demand for bagging has enormously increased. The baling of the cotton crop of the United States in 1882 consumed more than 100,000,000 pounds of jute. The product of the factories of Saint Louis has risen from 6,000,000 yards of bagging in 1876 to 13,000,000 yards in 1882, and, to meet the greater demand, several jute mills have recently been built in the Southern States,

The coarse webs just mentioned are the cheapest goods into which jute is ever manufactured. The finer fiber is wrought into an almost infinite variety of elegant and costly imitations.

Allusion was made in the former article to the beauty of these luxu-

* The summaries of the field products of 1882 are not yet quite complete, but the above figures, which are sufficiently exact approximations, are sanctioned by the statistician of the United States Agricultural Department.

rious fabrics. Their novelty and number are constantly increasing, but while from the want of accurate data the total worth of these rich textures is incalculable, yet any estimate which fails to recognize their enormous value would be eminently unjust to the textile importance of jute.

But it is not necessary to replace all the statistical illustrations of the former article with statements of present production. The latest agricultural reports of India are not yet accessible; and the intelligent reader, familiar with the recent statistics of American products, will be able to make the proper substitutions, and to observe with how much greater force the larger facts of to-day urge the establishment of the new industry in this country.

It is obvious from the preceding figures that jute is, next to cotton, the most important vegetable fiber in the world.

The greater part of this surprising development has taken place in the last quarter of a century.

LUXURIANT GROWTH OF JUTE IN THE UNITED STATES.

An interest in the economic welfare of the United States naturally suggests the inquiry whether an industry productive of so great affluence cannot be established in this country? The substantial identity of climate and soil in some districts of Bengal, and certain sections of the South, created a presumption that jute could be naturalized in the Gulf States. This probability, practical tests have strengthened into certainty. Hundreds of successful experiments have shown the ease with which jute can be raised in the Southern States. The results of many of these trials have been published in the reports of the Department of Agriculture. The accounts which, in return for distribution of seed, have been personally received would fill many pages. They are unanimous in their testimony. They prove beyond the possibility of intelligent doubt that, under proper conditions of soil and moisture, jute thrives on the borders of the Gulf with great luxuriance. But few of the tropic weeds, whose noxious exuberance seems to be in inverse ratio to their value, exceed it in rankness of growth. Some of the reports assert that jute can be raised as easily as Indian corn.

In 1881 Mr. Drummond, of the British legation at Washington, deemed the subject of jute culture in the United States worthy of a special report to the English Government. He says:

> Experiments were made in those (Southern) States, which proved that the cultivation and preparation of these fibers (ramie and jute) is practicable and profitable.
>
> Last year 1,500 packages of seed were distributed to the farmers in Louisiana, and reports have come in that the jute plant flourishes in every parish, growing in the alluvial soil to a height of 15 feet, and in the pine flats and on the hills to 10 and 12 feet.
>
> Now this is interesting to us, for all manufacturing countries have been dependent upon India for their supply of jute.

There is no need of further experiments to corroborate what has been

so fully demonstrated. It is now a well established fact that jute flourishes as luxuriantly in the United States as in India, and experts have testified that the fiber, when properly prepared, is quite equal to that of Bengal. If, then, the effort to introduce the culture of jute into this country is unsuccessful, the failure will not be due to the fact that the plant will not grow on American soil.

NEED OF MACHINERY.

From the outset some rapid and economical process for the removal of the fiber has been an indispensable condition of the prosperity of the jute industry in this country. In India the wages of adults are 10 or 15 cents a day. In exceptional cases of strength or skill the workman may obtain a quarter of a dollar, but in the rural districts where jute is raised the average pay for rude labor is probably not more than one-half of this sum. In the United States wages are so high that any manual competition with the hand work of India must inevitably prove a failure. It has been evident from the beginning that a mechanical treatment of the fiber was the only means of success, and consequently urgent appeals have been made to the inventive genius of our countrymen to meet the demand. It was confidently believed that American ingenuity, stimulated by the motive of public usefulness, and the hope of private riches, would conquer the difficulty. The confidence was not misplaced. The problem has been solved. Mr. T. Alber Smith, of Saint Louis, has invented a machine which will enable planters to determine whether jute can be profitably cultivated in the United States.

The following is the report of the first formal trial of Mr. Smith's machine:

WASHINGTON UNIVERSITY, *Saint Louis, September* 18, 1882.

DEAR SIRS: The jute machine of Mr. T. Alber Smith was tested in this city on the 12th of September. The mechanical conditions under which the experiment was tried were imperfect. The machine was operated by an engine that was at the same time driving all the machinery of a large workshop. Hence it was impossible to determine the amount of power required to actuate the jute machine.

The jute was home grown. It was raised near Brookhaven, Miss.

As the jute was cut before it was mature, the stalks were rather small and short. Their length ranged from five to seven feet. The stalks were entirely green and untrimmed. They were put into the machine with all their branches and leaves on, just as they came from the plantation. The jute stalks weighed eighty-seven pounds. They were run through the machine in thirty minutes. The available pulleys of the machine shop were so adjusted as to afford insufficient power.

It was deemed unwise for the sake of one experiment to incur the expense of alterations. Not more than one-third of the feeding platform was at any time filled. If the power had been adequate the time consumed in passing the stalks through the machine would not have exceeded ten minutes. After the operation the blades of the machine were found to be free from gum. An ingenious and effective application of water-jets obviates a difficulty that has heretofore been very embarrassing. The separation of the fiber from the ligneous stem was complete. Hardly a sliver of wood remained among the ribbons of fiber, and wherever a piece was found it was wholly detached and easily shaken out. The machine delivered the fiber straight and un-

tangled, while traveling belts carried away the woody fragments and left them in a heap by themselves. The eighty-seven pounds of stalks yielded twenty-seven pounds of green fiber. A pound and a half of green fiber were found in the refuse, but this waste consisted almost entirely of the fiber of the branches. These were so short that the fiber was not long enough to reach from the crushing to the separating rollers, and therefore was carried through and deposited with the refuse. The machine, of course, only removes the wood from the fiber. The process of retting is still necessary before the fiber is ready for commercial use. Three experiments in retting were tried. Two of them were conducted in the laboratory of Washington University. Fourteen and one-fourth pounds of green fiber steeped in a boiling bath of chemicals yielded two and one-fourth pounds of dry fiber. Ten and a half pounds of green fiber treated by the same method produced one pound and a half of dry fiber. The time spent in this process was exactly six hours.

The fibers are strong and easily separated, but somewhat darker than those retted in water. Two and one-fourth pounds of green fiber were placed in water, but the process of retting is not yet finished.

All of the steps described in these various tests were taken under my personal supervision. These facts will enable you to judge for yourselves of the commercial value of Mr. Smith's machine. It is very gratifying to me, after ten years of urgent appeal to inventors, that one of my own townsmen has devised a machine that is an important advance towards the solution of a great industrial problem.

Mr. Smith's invention simplifies the process of preparation. Heretofore water retting required ponds and rivers for the submersion of the unwieldly mass of stalks. But Mr. Smith's machine so greatly reduces the bulk that the fiber separated from the wood can easily be treated in vats. Water seems to be the most economical solvent of the gum which holds the jute fibers together. But water will do its work as cheaply in the United States as in India. Though chemistry may yet invent more effective methods, at present the cheapest way of separating the fibers is an immersion of the jute in vats of hot water. This process, impracticable when the whole stalks are handled, is readily feasible when only the fiber is treated. Ponds and rivers cannot be heated, but vats can be, and an equable temperature of any required degree can be maintained.

Mr. Smith's machine obviates a serious difficulty. In India the entire stalk is placed in water. If the stem is thick the fiber at the top is thin and delicate, while that at the foot is coarse and dense. As the water has access only to the outside of the stalk, the thicker bark and more compact fiber at the bottom prevent a uniformity of retting. Before the fiber at the butt has been sufficiently dissolved, the fiber at the top has become worthless from overretting. But Mr. Smith's machine, by stripping away the woody part of the stalk, and freely admitting the water to both sides of the fiber, insures a comparative equality of retting and prevents a material loss of fiber.

Hoping that the culture of jute in the Gulf States will soon develop into a national industry, and cordially thanking you for your gratifying acknowledgment of my own efforts to promote the success of this great interest,

I am, very respectfully, yours,

S. WATERHOUSE.

Messrs. JAMES M. PUTNAM and C. MENELAS.

The small quantity of fiber obtained in this test was due to the immaturity of the stalks. The growth of the jute was retarded by an excess of moisture. The stems were short, slender, and unripe; being imperfectly developed, they were deficient in fiber. The poverty of results could not be ascribed to the method of treatment, for, with the exception of a surprisingly small amount of waste, the machine saved all the fiber the stalks contained.

In the following October the machine was removed to the plantation of Mr. C. Menelas, near Brookhaven, Miss. A portion of the 15 acres of jute which the proprietor had planted was expressly reserved for a second trial of Mr. Smith's machine.

It was now so late in the season that, in consequence of over-ripeness, the stalks were dry and ligneous. The jute, too woody for textile use, was worthless except for the simple purpose of a test. The machine was therefore subjected to such a trial as it would never have to encounter in actual service, for the fiber is finest when the plant is cut in the time of flowerage, and then the green and pliant stems do not expose the machinery to violent strains. But, though repeated tests were made with hard and intractable stalks, the operation of the machine was satisfactory. The severe ordeal, which its proper duty would never require it to pass, developed no serious defects. During all of the numerous trials the action of the blades was never obstructed by any adhesions of gum.

PROFITS.

The capacity of Mr. Smith's present machine is 15,000 pounds of green stalks in a day of ten hours. The day's work of the larger machines which it is proposed hereafter to build will be 30,000 pounds. The service of the machine requires three men. The inventor authorizes the statement that the total cost of raising jute and of preparing it for market by his process will not exceed 2 or 2½ cents a pound. Calculations based upon this estimate show that, even at current rates, which are exceptionally low, jute is a more profitable crop than cotton. Planters, whose long and varied experience entitles their judgments to respect, confirm the assertion. The bagging mills of the South offer for home-grown jute the same price which they have to pay for the foreign article. The freight from Calcutta to New York is now about half a cent a pound. The cost of foreign jute in the American market is still further enhanced by charges of Indian factors for purchase and packing, brokers' commissions, marine insurance, and the United States impost. All these expenses, which the American importer cannot evade, favor the domestic production of jute. Aided by mechanical facilities and a judicious tariff, the protective duty which distance imposes will mature a nascent industry into a sturdy growth.

But it is alleged that the present tariff on jute, which levies a higher rate on the crude material than on the textile product, unwisely discriminates against home manufactures. So grave a charge challenges the attention of American statesmen. To devise a protection which, with just encouragements, will foster an industry abounding in possibilities of national enrichment, is the congenial task of patriotic Congressmen. If the endeavor to introduce the new staple should ultimately fail, it would undoubtedly be wise to remove the tariff on raw jute; but till that event, which no signs at present portend, it would be an act of impolicy

and of unfriendliness to American prosperity to withdraw from a young and struggling industry the guardian care of the government.

Some planters have feared that the competition of India would prove fatal to the profits of jute culture in the United States. An illustration will show the probable groundlessness of this apprehension.

There are lands in India as rich as any the sun shines on. The luxuriance of the vegetation attests the fertility of the soil. The plains and intervals of India resemble the prairies and alluvial bottoms of the Mississippi Valley. Unlimited levies of cheap labor can be enlisted in the service of agriculture. Yet, notwithstanding the productiveness of the soil and the lowness of wages, no American planter dreads Indian rivalry in the cultivation of cotton. The quality of the Indian staple is noticeably inferior. One of the remarkable sights witnessed in a personal tour through India was thousands of acres of cotton which seemed too poor to gather. Probably something of the excellence of American cotton is attributable to peculiarities of air and soil. The exceptional favors which nature has bestowed upon the "Sea Islands" exclude their product from this general comparision. But it is not yet known how much of the qualities commonly ascribed to climatic conditions is really due to differences of cultivation. If the population of India and the United States should change places, it is not certain that Hindoostan would not obtain the supremacy in cotton-growing that the South now holds. At all events, after the most liberal allowance for the effect of atmospheric influences, the superiority of the American staple is largely due to better methods of agriculture. It is simply incredible that, on similar soil, the rude tillage of India should produce as fruitful results as the enlightened culture of the United States. The yield per acre of American cotton is not only far more abundant, but the fiber is longer and finer than that of the East Indies. India enjoys no special and exclusive facilities for raising jute. Its industrial advantages are equally favorable to the production of cotton. If, then, with all the benefits of cheap labor, it cannot maintain an ascendency in growing cotton, how can it prevent profitable competition in the cultivation of jute? In the case of both fibers, the skillful use of machinery is an essential factor of American success.

The raising of cotton is laborious and costly. From the turning of the furrow to the completion of the harvest, unremitting care is necessary to insure a plentiful crop. But the tillage of jute is easy and inexpensive. The operations after the stalks have been gathered require the greatest work and outlay. This difference increases the probability of success in the attempt to raise jute in the United States; for a large part of the toil expended upon the culture of cotton is necessarily manual. But a great portion of the work which prepares jute for the market can be performed by mechanical processes. Hence the cheap labor of India is more favorable to cotton than it is to jute; for, as in-

telligence, trained to the use of the best methods, does not exist in Hindoostan, the rude physical toil for which alone the natives are fit can be more effectively applied to the growth of cotton than to the preparation of jute. If, then, the East Indians, though aided by so signal an advantage, could monopolize the supply of cotton, is it not just to infer that a dexterous application of labor-saving machinery will enable Americans to compete with their foreign rivals in the production of jute?

The foregoing facts and reasons certainly seem to indicate that fair profits will reward the cultivators of jute in the United States.

ADAPTATION OF THE SOUTHERN STATES TO JUTE CULTURE.

In India jute is raised almost exclusively on ground that has been flooded by the annual overflow of the rivers. The alluvial deposit left by the inundation forms just the soil which the plant requires. The bottom-lands of the lower Mississippi closely resemble the jute fields of India. There are in the South extensive tracts not suited to the cultivation of sugar or cotton, but well adapted to the growth of jute. If the plant will flourish on the salt marshes that fringe the Gulf, the area of land available for this tillage is almost immeasurable. The capacity of these lands should be thoroughly tested. If suited to the production of jute, they can be converted into prolific sources of public prosperity.

In India the mass of the people has an inertia which the forces of modern civilization can but sluggishly move. Utterly unacquainted with improved processes, the native workmen plod on in the unthrifty ways of their fathers. By always sending the best jute to market and reserving the poorest for seed they have produced a marked deterioration in the quality of the fiber. The inferiority of recent products is a matter of universal observation and complaint. A desire to escape the oppressive exaction of Indian monopolists, as well as to secure better material, has led the manufacturers of Dundee to try extensive and costly experiments in Egypt. But, while the soil of the delta is well suited to the production of jute, the intellectual and industrial character of its inhabitants does not indicate a successful result. The same lethargy and indifference to modern methods which are proving so disastrous in India will in all probability insure failure in Egypt.

But the South has cheap and docile labor which can be easily trained to the requisite degree of skill. Intelligent experts, superintending every operation of the new industry, will apply to the cultivation and treatment of jute the best processes which science has discovered. Experience will determine the exact conditions of soil and moisture best adapted to the growth of the plant, and a careful selection of the seed of the finest stalks will soon improve the quality of the fiber. It is probable that, in the course of years, American grown jute will attain an excellence as high and distinctive as that of Sea Island cotton. A vigilant attention to every means of improvement cannot fail to pro-

duce a fiber of superior strength, fineness, and beauty. The yield per acre in the South has often been larger than that of India. Scientific agriculture, enriching the soil with a generous supply of plant-food and preventing its rapid exhaustion by a judicious rotation of crops, ought assuredly to develop a greater fertility than that produced by a system of ignorant and wasteful tillage.

The excellence of the fiber is generally proportioned to the freedom of the plant from branches. When there are no off-shoots, the filaments have greater length, softness, and gloss. But thick sowing seems to be the only practicable way of preventing branching. If, therefore, the seed is sown broadcast, it should be scattered with a liberal hand; but if it is planted in drills, the rows should be near each other. Then the struggle for light and air will cause the plants to grow tall, straight, and branchless.

In India the plan of planting in successive months has been tried. The example may be worthy of American imitation. If the seed were sown at intervals in April, May, and June, as the harvest would not all be gathered at one time, a less number of machines and a smaller force of workmen would be required to handle the crop. In a double sense, the smaller the plant the less would be the outlay. An income at seasons of the year when the returns of other crops are not available would not be the least important advantage which this system would confer upon the planter. The laborers, too, would obtain uninterrupted employment and regular wages during months in which they ordinarily have but little to do.

RETTING.

In India practical experience has shown that the process of retting is hastened by steeping the stalks in stagnant water. In a stream the operation takes more time, but the fiber has greater whiteness, strength, and luster. The construction of vats, while promoting cleanliness and the economic handling of the jute, would permit the use of hot water, steam, or chemicals for the removal of the gum. Chemistry, which has in modern times so usefully simplified many industrial processes, may yet reduce the time of retting to a few hours. But, unless the element of time becomes very important, water will always be the cheapest solvent. In India the average duration of retting is 10 or 15 days. So short a period will not allow the substitution of any costly process. Whatever takes the place of water must save the difference in expense by economy of time.

LABOR-SAVING FACILITIES.

In order successfully to compete with the cheap labor of India and the mechanical skill of Dundee the most efficient agencies must be employed. The plowing, planting, cultivating, and cutting should be done by the best implements which ingenuity has devised to lessen the

toils of agriculture. The ribbons of fiber, swiftly stripped from the stalks by fingers of steel, ought to be placed on large frames, which, under the control of steam, would move up and down in the retting vats like an elevator. All the processes of manufacture must be performed by the latest labor-saving appliances. It is only by such econ. omies that Americans can hope to excel foreign competition.

If the South raises more jute than the needs of this country require, it may yet export the fiber to Dundee, as it does cotton to Liverpool. In the event of success in the cultivation of jute in this country, some of the Dundee manufacturers have intimated their willingness to establish factories in the United States.

PROSPECTS AND SUGGESTIONS.

The Americans are actively prosecuting the experimental growth of jute in various parts of their country, while we are, as a government, doing nothing to extend it.

These words, uttered in 1873 by Hon. George Campbell, the lieutenant-governor of India, have to-day a fresh and dangerous significance. The attention which the Southern States are now giving to the subject of jute-culture is deep and unexampled. The interest is akin to public enthusiasm. Never from the inception of the attempt to naturalize jute in this country have the auguries of success been so propitious. The very uncertainty of other staples strongly recommends the cultivation of the Indian plant. Cotton and sugar are not sure crops. The havoc of worms and insects often disappoint the hopes of the planter. But jute is, seemingly, offensive to these destructive pests. Its bitter and acrid qualities are said to drive them from its presence. It might, indeed, be used as a vegetable police to guard other crops from attack. If, in the discharge of its sentinel duties, it should merely shield cotton from the insidious inroads of its enemies, its cultivation for exclusively defensive service would annually save the South millions of dollars. But when, in addition to its protective virtues, jute has a textile value which is one of the world's great sources of fibrous wealth, a neglect to cultivate it would betray a culpable indifference to the prosperity of the South. A partial failure of the harvest has not infrequently taught the danger of a too great reliance upon a single staple. The planters have learned, under the costly tuition of experience, to diversify their industries. If there is only one production, its blight involves the farmer in irremediable loss; but if there is a variety of products, when one crop fails there are still other resources to retrieve the disaster. Hence, if there were no lands in the South suited to the culture of jute but those which are now allotted to cotton and sugar, it would be the dictate of economic prudence to withdraw a proportionate share from its present use and devote it to the tillage of the new staple.

The movement in favor of the proposed industry is now so earnest and widespread that it cannot stop until the question whether jute can

be lucratively grown in the United States has been definitely answered. Now, for the first time, there is a means of testing the possibility of profit by business standards, and probably thousands of planters will hasten to try the experiment. But, in order to avoid disappointment, there should be an intelligent concert of action. The cultivation of small quantities of jute on farms remote from railroads and navigable streams would hardly prove remunerative. Doubtless large estates would raise enough jute to justify the purchase of the mechanical conveniences which its preparation would require. The smaller farmers, whose limited crops would scarcely warrant the individual outlay, could combine and buy a machine. Seemingly it would be the best plan to build vats and factories in central and easily accessible places. If it were necessary for each planter to possess the costly appliances requisite for all of the operations, there could be no possible profit in the business. But, if the great bulk of the jute were removed by decortication, the compact masses of fiber could easily be sent to the factory, and there, where all the apparatus for retting and manufacturing existed, the material could be cheaply handled. By sagacious and economical co-operation the planters of the South may derive profitable returns from the culture of the Indian staple.

No vigor of language can too earnestly express my conviction that a great industry, productive of vast opulence, now awaits the hand of southern enterprise. The lapse of time has only strengthened my belief that the Southern States can, by organized effort, produce a new vegetable fiber, which, ranking next to cotton in value, will not only enrich themselves, but also increase the textile resources of the world.

With a renewed expression of my obligations for your personal courtesies, and with congratulations that your administration of the Department of Agriculture will witness the opening of a plenteous source of public wealth,

I am, very respectfully, yours,

S. WATERHOUSE.

WASHINGTON UNIVERSITY,
Saint Louis, Mo., February 15, 1883.

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DEPARTMENT OF AGRICULTURE.

RESULTS

OF

FIELD EXPERIMENTS

WITH

VARIOUS FERTILIZERS.

BY

PROF. W. O. ATWATER, PH. D.

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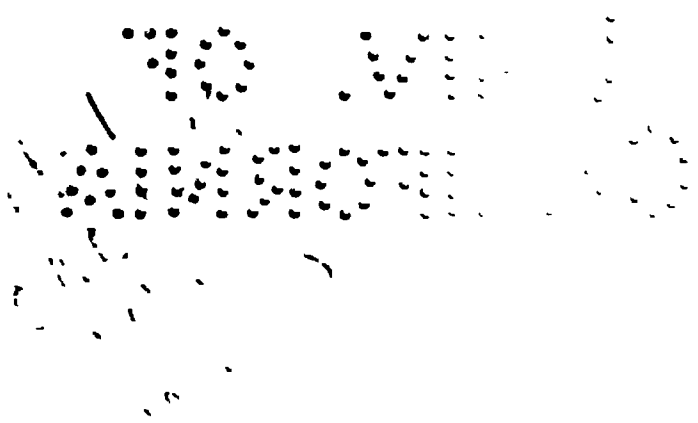

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RESULTS OF FIELD EXPERIMENTS WITH VARIOUS FERTILIZERS.

INTRODUCTION.

The objects of the present article are:

1. To describe a series of experiments conducted on similar plans, but under widely varying conditions, by some hundreds of scientific and practical agriculturists in all of the older and some of the newer States of the Union.

2. To set forth the main results of these experiments, and the inferences to be derived from them.

3. To suggest plans for further experiments under the auspices of the United States Department of Agriculture.

In introducing the subject, it may be well to briefly recapitulate some of the main results of the experiments. I may perhaps be permitted to quote from an address delivered at a convention held at the Department of Agriculture in January, 1882:

Farmers, from Canada to Texas, are spending millions upon millions of dollars every year for guano, fish scrap, ammoniated superphosphates, nitrate of soda, and the like. Ostensibly, they are buying the fertilizers at from $20 to $100 per ton. Actually, they are buying nitrogen at from 15 to 40 cents per pound. But need the farmer spend so much for nitrogen? Or might he use more with profit? These are questions that no professor of agriculture can answer. Indeed, no chemist or botanist to-day can so much as tell him how the different plants he cultivates stand related to nitrogen, for what ones he must buy it, and what ones he may use in his rotation to gather it from nature's stores and furnish it to him without money and without price save the cost of tillage.

The question of the nitrogen supply is only one of a great many whose solution is most urgently demanded. We must know how to feed our plants or go without food ourselves. We need more light. Some must come from the laboratory and the greenhouse; some must be sought in the field.

Five years ago, while director of the Connecticut agricultural experiment station, I suggested some field experiments with fertilizers to be carried out by farmers for the purpoee of studying the needs of their soils and the best materials to supply them. The outgrowth of these, in the form of extended series of experiments during four successive seasons, has been stated briefly in the American Agriculturist, and, in more detail, in the Reports of the Connecticut Board of Agriculture for 1877, 1878, 1879, and 1880. The experiments of 1881 have not yet been published in detail, but a few of the more important results will be given herewith.

With the sets of experimental fertilizers were sent blanks on which any who should choose were invited to send reports of their experiments. Nearly three hundred experiments have been reported. They come from colleges, experiment stations, and individual farmers in all the States east and from some west of the Mississippi, and from several of the British provinces. The quality of the work, as indicated by the reports, is most gratifying.

NEED OF MORE INFORMATION.

Hitherto we have been compelled to rely mainly upon European investigations for our facts regarding the nutrition of plants and the action of manures. Our information is incomplete, and even the foremost teachers may give us wrong counsel.

Dr. J. B. Lawes, of Rothamsted, England, unquestionably the foremost field experimenter in the world, in writing, in 1873, to the treasurer of the Massachusetts Society for the Promotion of Agriculture, said: "The best possible manure for all graminaceous crops—wheat, barley, maize (corn), oats, sugar-cane, rice, and pasture grass—is a mixture of superphosphate and nitrate of soda. * * * Potash is generally found in sufficient quantities in soils, and the artificial supply is not required." In more than half of our experiments with corn, and in nearly all with potatoes, the crops have been materially aided by potash salts, and without potash in the fertilizer they have often failed. The mixture which Dr. Lawes regards as "the best possible manure" for corn was sometimes very useful, and sometimes brought almost no return. The potash, which his experience in England led him to consider superfluous, was here, in many cases, the most necessary of all the fertilizing ingredients.

Several years ago the professor of agriculture of one of our leading agricultural colleges proposed a series of formulas for different crops. With the rest was one for corn, which, with a moderate proportion of potash and a small amount of phosphoric acid, supplied nitrogen at the rate of 64 pounds and at a cost of over $15 per acre.

Professor Ville, of France, whose theories of plant nutrition and formulas for fertilizers have been very widely published and followed in Europe and the United States, proposes also a formula for corn, which would cost from $19 to $27, and containing at a cost of from $5 to $9 per acre, according to the kinds of materials employed.

Both of these gentlemen thus assumed that to raise corn successfully will require large and costly supplies of nitrogen. The question whether corn can gather its own nitrogen, like clover, or demands an artificial supply, like wheat, whether it is an "exhausting" or a "renovating" crop, has been much discussed. Upon its answer depends the success of corn-growing in our older States. The experiments referred to bear emphatic testimony upon this point. The corn has almost uniformly refused to respond to nitrogen in fertilizers, and persists in getting on well without any artificial supply. But it has been largely benefited by phosphoric acid, and often by potash. The formulas above, with their large and excessively expensive amounts of nitrogen, would, in nearly every case, have involved great waste of both fertilizer and money.

VARIATIONS IN DEMANDS OF DIFFERENT SOILS FOR PLANT-FOOD.

Another outcome of these experiments which seems to me especially useful, is found in the very forcible illustration they give to the differences of soils, as regards their deficiencies of plant-food, and the effects of different fertilizing materials used upon them. In some places, phosphoric acid; in others, potash; in others, nitrogen; in others, lime; and in still others, several or all of these ingredients have proven indispensable in fertilizers to secure the growth of crops.

Mr. W. I. Bartholemew, of Putnam, Conn., has been conducting the experiments for five years. In every trial every plot which has received phosphoric acid has given a more or less satisfactory return, and every one without phosphoric acid has failed. Nitrogen and potash have each increased the yield of corn, but neither has brought enough increase to pay its cost, and the loss has been larger or smaller, as more or less was used. Potatoes, on the other hand, have responded profitably to all the ingredients named.

Mr. C. Sage, of Middletown, Conn., has had a very different experience. The phosphoric acid which Mr. Bartholemew finds so effective helps his plants but very little. Nitrogen proves as inefficient with him as with Mr. Bartholemew. But potash, which on Mr. Bartholemew's land had scarely any effect, proves with Mr. Sage decidedly the most effective ingredient. One hundred and fifty pounds per acre of muriate of potash, which costs Mr. Sage $3.50, has made a difference between corn so poor as to be hardly worth husking, and 60 bushels or more of excellent shelled corn per acre, and a fine growth of stalks.

Mr. W. C. Newton, of Durham, Conn., has a still different experience. Potash is as useless on his land as on Mr. Bartholemew's; phosphoric acid has no more effect than with Mr. Sage, but the nitrogen which both the latter gentlemen found so inefficient, is on Mr. Newton's soil the most efficient of all. Corn responds uniformly and largely to nitrogen in every form and on every plot where Mr. Newton has used it. The yield rises and falls regularly with the amount of nitrogen applied, and the same results have been obtained in different experiments in different seasons, in the same field. Mr. Newton's experience, however, is an exception, and an unusual one.

But while in the three cases above mentioned individual ingredients were profitable, and the so-called "complete fertilizers" were not warranted by the experience, in other cases all of the fertilizing ingredients named have been found necessary, and the omission of either is followed by a loss of produce.

Thus Mr. Fairchild, Middletown, Conn., finds the complete fertilizer most profitable in every case. Whenever he omits any of the important ingredients a small yield results. Mr. Fairchild further finds that the amount and form of combination of the fertilizing ingredients are important matters, and his experiments are showing him in what forms and ways they may be most advantageously used.

And, finally, there are many cases in which no artificial supply of plant-food brings a profitable return. Some soils will give good returns if manured, and others, without previous draining, irrigation, amendment by tillage, use of lime, marl, or otherwise, will not.

Artificial fertilizers, rightly used, must become, as indeed they already are getting to be, among the most potent means for the restoration of our depleted soils; but we do not yet know how to use them, and it is necessary, not only that new facts shall be learned, but that those

already known shall be better understood. For both these purposes I believe the experiments referred to are eminently useful.

SUGGESTIONS FOR EXPERIMENTING.

With reference to experiments with fertilizers the present article urges that it is only by selecting specific and narrow questions, and working at them systematically and continuously, that we shall secure the most valuable results. There has been too much firing at random. We need to choose proper points of attack, be sure of our aim, and concentrate our fire until a breach is made, and we need not only to work rightly, but to work together. Experiments with a common object, on a common plan, conducted by intelligent and careful investigators in different places, under different and actually observed and recorded conditions, are needed to bring the results which scientific agriculture so pressingly demands.

I have ventured to add further two suggestions; the first, and a perfectly obvious one is, that to get the most complete results, we need—

I. Field experiments, to include—

a. The culture of plants on plots of land treated with different manures, and careful weighings and measurements of produce.

b. Where practicable, chemical and physical studies of the soil.

c. In many cases, chemical analyses of the plants.

II. Pot experiments, in which the conditions can be definitely known and controlled, and the needed studies of soil and plants be carried out with equal or greater convenience and accuracy.

The second is, that there ought to be in the various sections of the country chemical and physical surveys of the land in the behalf of agriculture, as there have been topographical and geological surveys in the behalf of other industries and interests. And in fact this is precisely the direction in which we are tending in this experimental work.

PLAN OF THE PRESENT ARTICLE.

In this attempt to collate and set forth the results of the work of so many intelligent and earnest experimenters, it has been necessary to omit much material that would have been of interest had we space for its description, and to condense as much as possible the accounts that are given. The arrangement of topics is in brief as follows:

1. Explanations of special experiments upon the question of the nitrogen supply.
2. Explanations of so-called general experiments.
3. Notes upon individual experiments.
4. General discussion of experiments.
5. Results and practical applications.
6. Plans for co-operative experiments.
7. The details of results in the form of tables, &c., in the appendix.

EXPERIMENTS UPON NITROGEN SUPPLIES.

The experiments of which it is proposed to give an account here are so numerous that detailed descriptions of the work of individual experimenters, except in a few cases, would be hardly practicable. I will therefore attempt to group them in three classes, and describe the several classes separately:

1. Special nitrogen experiments, including a number which have had for their object the study of the feeding capacities of plants, with especial reference to the nitrogen supply.

2. General experiments which were proposed primarily for testing the wants of soils and crops and the best means of supplying them; but which, being on a common plan and large in number, likewise afford data of great value.

3. Other experiments, on plans which, though different from the above, are sufficiently similar to them to allow of comparison.

These have been performed by a number of professors in agricultural colleges, and intelligent, practical farmers in several States. The specific questions upon which information is sought in the experiments may be stated thus:

1st. How do the plants experimented with get on with the "mineral" fertilizers, such as are supplied by superphosphates and potash salts?

2d. More especially, how do they respond to nitrogen when added, in different forms and amounts, to the mineral fertilizers?

3d. And, finally, what inferences may we draw as to the feeding capacities of the plants, their power to gather their food from soil and air, and the effects of different materials upon their growth, especial reference being made to the nitrogen supply?

For the systematic study of these questions a special "nitrogen experiment" was devised in 1878, and conducted by several gentlemen. Similar series were repeated in 1879, and with some variations in 1880. The plan and purpose of the experiments are set forth in the following statements from a four-page circular, which was sent to the experimenters of 1881, similar ones having been prepared for those of previous years.*

* In the tabular statements of results of the experiments (Appendix, Tables I, II, and III), some differences will be noticed between the schedules of 1881 and those of the previous seasons.

In the experiments of 1881 nitrogen is supplied in Group IV as ammonia, and in Group V as organic nitrogen, while in the experiments of 1878 and 1880, as may be seen in Table I, the nitrogen is supplied in Group IV as "nitrogen" mixture, and in Group V in other forms. A further difference is found in Group V, which, in 1878 and 1880, supplied the nitrogen as a two-third ration, but in 1881 in varying quantities.

Another year's experience has suggested some slight changes in the quantities of phosphoric acid and potash, the former being somewhat increased and the latter diminished, as will be seen by reference to the schedule of special nitrogen experi-

SPECIAL EXPERIMENTS FOR NITROGEN TESTS, 1881—EXPLANATIONS.

The object of this experiment is to test the effects of nitrogenous fertilizers in different amounts and combinations upon the growth of the plant, and inferentially its capacity to gather its nitrogen from natural sources.

The fertilizers.—The ingredients and amounts are such as are used in ordinary practice, phosphoric acid and potash being supplied in about the proportions that occur in a corn crop of fifty or sixty bushels, and nitrogen in one-third, two-thirds, and full amount in same crop.

Forms of nitrogen.—The nitrogen is supplied as nitric acid in nitrate of soda; as ammonia in sulphate of ammonia, and as organic nitrogen in dried blood.

Quantities of nitrogen.—The nitrogen is applied at the rate of 24 pounds per acre in "one-third ration"; 48 pounds per acre in "two-thirds ration"; and 72 pounds per acre in "full ration."

Arrangement of plots and fertilizers.—The ingredients are supplied as:

Partial fertilizers.	Group I, Nos. 1–3. Each by itself. Group II, Nos. 4–6. Two by two.	Thus testing the effects of ingredients separately and capacity of soil.
Complete fertilizers.	Group III, Nos. 7–9. Nitrogen as nitric acid in nitrate of soda..... Group IV, Nos. 10–12. Nitrogen as ammonia in sulphate of ammonia.. Group V, Nos. 13–15. Nitrogen as organic nitrogen in dried blood.....	Nitrogen in one-third, two-thirds, full ration.

ments in the chapter beyond on proposed plans for co-operative experiments. It seems to me that this latter schedule and that of 1882, in the light of past experience, is well adapted to its purpose, and will very likely be continued for some time to come.

EXPERIMENTAL FERTILIZERS—SPECIAL NITROGEN SET, 1881.

No.	Materials.	Amounts.	
		Acre set for $\frac{1}{10}$ acre plots.	Two-acre set for $\frac{1}{10}$ acre plots.
		Pounds.	*Pounds.*
1	Nitrate of soda	7½	15
2	Superphosphate	15	30
3	Muriate of potash	7½	15
4	Nitrate of soda	7½	15
	Superphosphate	15	30
5	Nitrate of soda	7½	15
	Muriate of potash	7½	15
6	Superphosphate, Muriate of potash } Mixed minerals	15	30
		7½	15
7	Mixed minerals, as No. 6	22½	45
	Nitrate of soda	7½	15
8	Mixed minerals, as No. 6	22½	45
	Nitrate of soda	15	30
9	Mixed minerals, as No. 6	22½	45
	Nitrate of soda	22½	45
10	Mixed minerals, as No. 6	22½	45
	Sulphate of ammonia	5⅝	11¼
11	Mixed minerals, as No. 6	22½	45
	Sulphate of ammonia	11¼	22½
12	Mixed minerals, as No. 6	22½	45
	Sulphate of ammonia	16⅞	33¾
13	Mixed minerals, as No. 6	22½	45
	Dried blood	11¼	22½
14	Mixed minerals, as No. 6	22½	45
	Dried blood	22½	45
15	Mixed minerals, as No. 6	22½	45
	Dried blood	33¾	67½
6a	Superphosphate, Muriate of potash } Mixed minerals	15	30
		7½	15
6b	Superphosphate, Muriate of potash } Mixed minerals	15	30
		7½	15
6c	Superphosphate, Muriate of potash } Mixed minerals	15	30
		7½	15

Nos. 6*a*, 6*b*, and 6*c* are simply duplicates of mixed minerals No. 6.

This schedule provides for twenty plots, of which two are unmanured, and eighteen supplied with the experimental fertilizers.

No. 6, the mixture of superphosphate and muriate of potash, is designated as "mixed minerals." This is duplicated in Nos. 6*a*, 6*b*, and 6*c*. The same mixture forms the basis of Nos. 7 to 15, inclusive, which consist of "mixed minerals," with the addition of nitrogen compounds.

The fertilizers were supplied, in part at cost and in part gratuitously, by the Mapes Formula and Peruvian Guano Company, to whose interest and enthusiasm in promoting the experiments especial thanks are due.

Each set of experimental fertilizers was accompanied by directions for use (see above) and a blank, on which the experimenters were requested to record their observations and the results obtained.

The blanks were sheets of paper 12 by 19 inches in size, with spaces for numerous details as to soil, weather, culture, produce, &c. The details provided for were very similar to those set forth in the report of the experiments by Mr. Atwood, in the chapter beyond, on the subject of general experiments. The general plans and directions for the experiments are the same as set forth in the chapter on plans for co-operative experiments beyond.

The following is a list of experimenters and experiments on the above schedules reported to the writer. Some others, notably one by Prof. H. C. White, of the College of Agricultural and Mechanic Arts, and the Agricultural Experiment Station at Athens, Ga., were not reported, having, as I understand, been so injured by drouth and accidents as to make their publication less desirable:

A. 1878.—Prof. J. R. FARRINGTON, Maine Agricultural College, Orono. *Corn.*

B. 1878.—W. I. BARTHOLEMEW, Putnam, Conn. *Corn.*

C. 1879, '80, and '81.—As above. *Corn* and *potatoes*, side by side.

D. 1878.—CHESTER SAGE, Middletown, Conn. *Corn.*

E. 1879.—As above. *Corn.*

F. 1879.—Col. J. B. MEAD, Randolph, Vt., under the auspices of the University of Vermont and State Agricultural College. *Corn.*

G. 1880.—Prof. W. H. JORDAN, Maine Agricultural College, Orono. *Corn.*

H. 1880.—EDWARD HICKS, Old Westbury (L. I.), N. Y. *Corn.*

I. 1880.—CHARLES FAIRCHILD, Middletown, Conn. *Corn.*

J. 1881.—As above. *Oats and potatoes*, side by side.

K. 1880.—WILLIAM C. NEWTON, Durham, Conn. *Corn.*

L. 1881.—As above. *Corn.*

M. 1881.—Prof. C. L. INGERSOLL, Purdue University, La Fayette, Ind. *Corn* and *potatoes*, side by side.

N. 1881.—C. E. THORNE, Ohio State University, Columbus, Ohio. *Corn.*

O. 1881.—J. W. PIERCE, West Millbury, Mass. *Corn.*

P. 1881.—EDWARD HICKS, Old Westbury, N. Y. *Corn.*

Q. 1881.—Prof. SAMUEL JOHNSON, Michigan Agricultural College, Lansing, Mich. *Corn.*

R. 1881.—Prof. W. C. STUBBS, Alabama Agricultural and Mechanical College, Auburn, Ala. *Cotton.*

S. 1881.—J. M. MANNING, Taunton, Mass. *Clover.*

The main results of the special nitrogen experiments are stated in the appendix tables I, II, and III. Details of the reports are also given in the appendix.

The following account of Mr. Fairchild's experiments in 1881 with oats and potatoes will serve to illustrate the plan and results.

It will be noticed that the arrangement of the groups with the nitrogenous fertilizers is slightly different from that mentioned above. The experiments were commenced in 1879, and on a schedule which has been slightly altered for the experiments of succeeding years, as already explained.

EFFECTS OF NITROGENOUS FERTILIZERS

EXPERIMENTS WITH OATS AND POTATOES IN 1881. BY MR. CHARLES FAIRCHILD, OF MIDDLETOWN, CONN.

[Soil, dark loam, loam subsoil, moist; had oats in 1877, rye in 1878, grass in 1879, and corn fertilized as below in 1880.]

	Kind and amount of fertilizers per acre.	YIELD PER ACRE.			INCREASE PER ACRE.			Cost of fertilizers, freight, &c.	PECUNIARY RESULTS.			
		Oats.		Potatoes.	Oats.		Potatoes.		Val. of increase		Grain.	
		Grain.	Straw.		Grain.	Straw.			Oats.	Potatoes.	Oats.	Potatoes.
		Bush.	*Lbs.*	*Bush*	*Bush.*	*Lbs.*	*Bush.*					
0	No manure	26. 9	1, 160	28. 0								
1	Nitrogen mixture, 150 pounds	38. 1	1, 520	42. 0	11 3	627	13. 3	$6 00	$9 75	$9 98	$3 95	$3 98
2	Superphosphate, 300 pounds	33. 8	1, 300	56. 0	6. 9	607	27 3	6 00	7 42	20 48	1 42	14 48
3	Muriate of potash, 150 pounds	31. 3	1, 720	60. 9	4. 4	527	31 3	3 75	5 50	23 48	1 75	19 73
4	Nitrogen mixture, 150 pounds, and superphosphate, 300 pounds	51. 9	2, 660	94. 7	25. 0	1, 467	66. 0	12 00	22 55	49 50	10 55	37 50
5	Nitrogen mixture, 150 pounds, and muriate of potash, 150 pounds	42. 5	2, 160	68. 0	15. 6	967	39. 3	9 75	14 40	29 48	4 65	19 73
6	Superphosphate, 300 pounds, and mur of pot., 150 pounds, "mixed minerals"	33. 8	2, 280	90. 7	6. 9	1, 087	62. 0	9 75	10 30	46 50	55	36 75
7	Mixed minerals (as No 6), 450 pounds, and nitrate of soda, 150 pounds	54. 4	3, 500	124. 7	27. 5	2, 337	96. 9	15 75	28 97	72 00	13 22	54 25
8	Mixed minerals, 450 pounds, and nitrate of soda, 300 pounds	59. 4	3, 880	188. 7	32. 5	2, 667	110. 0	21 75	33 88	82 50	12 13	60 75
9	Mixed minerals 450 pounds, and nitrate of soda, 450 pounds	59. 4	4, 380	120. 0	32. 5	3, 107	91. 3	27 75	36 52	68 40	8 77	40 65
6a	Mixed minerals (as No. 6), 450 pounds	36. 3	1, 760	94. 0	9. 4	567	65. 3	9 75	8 56	48 98	1 19	39 23
00	No manure	27. 5	1, 280	46. 7								
10	Mixed minerals, 450 pounds, and nitrogen mixture, 150 pounds	51. 0	3, 140	122. 7	25. 0	1, 947	94. 0	15 75	25 43	70 50	9 68	54 75
11	Mixed minerals, 450 pounds, and nitrogen mixture, 300 pounds	55. 6	3, 380	144. 7	28. 8	2, 187	116. 0	21 75	28 93	87 00	7 10	65 25
12	Mixed minerals, 450 pounds, and nitrogen mixture, 450 pounds	59. 4	3, 780	144. 7	32. 5	2, 587	116. 0	27 75	33 40	87 00	5 65	59 25
6b	Mixed minerals (as No. 6), 450 pounds	33. 8	1, 760	110. 0	6. 9	567	81. 3	9 75	7 18	60 98	2 57	51 23
13	Mixed minerals, 450 pounds, and sulphate of ammonia, 225 pounds	61. 9	3, 700	185. 3	35. 0	2, 507	106. 6	21 75	34 29	79 95	12 54	58 20
14	Mixed minerals, 560 pounds, and dried blood, 450 pounds	53. 8	3, 080	134. 7	26. 9	1, 887	106. 0	21 75	26 10	79 50	4 35	57 75
15	Peruvian guano, 450 pounds, and muriate of potash, 150 pounds	54. 4	3, 980	133. 3	27. 5	1, 787	104. 6	21 75	25 85	78 45	4 10	56 70
16	Mixed minerals (as No. 6), 450 pounds	35. 0	1, 760	96. 0	8. 1	567	67 3	9 75	7 87	50 48	1 88	40 73
000	No manure	26. 3	1, 120	29. 3								
A	Bone, 150 pounds	31. 3	1, 680	54. 0	4. 4	487	25. 3	3 00	5 33	18 98	2 33	15 98
B	Bone, 150 pounds and muriate of potash, 100 pounds	35. 0	1, 960	74. 0	8. 1	767	45. 3	5 50	9 07	33 98	4 57	28 48
C	Same as B and sulphate of ammonia, 100 pounds	45. 6	1, 980		18. 8	787		10 75	15 03		4 28	

The plots were parallel strips of eight square rods each. In 1880 corn was planted over the whole field. In 1881 the whole was divided into halves by a line crossing the plots, and one-half devoted to oats and the other half to potatoes. Mr. Fairchild proposes to follow with wheat and grass, thus running the experiment through a regular rotation of several years the same fertilizers being applied to the same plots year after year, while the crops succeed each other as in ordinary farm practice. The cost of the fertilizers includes $5 per ton for freight and applying. Potatoes are estimated at 75 cents per bushel, oats at 55 cents, and oat straw at $12 per ton, which are fair rates for the region and season.

Before discussing these special experiments, a description of the other experiments will, perhaps, be in place.

GENERAL EXPERIMENTS.

SOIL TESTS WITH FERTILIZERS.

While director of the Connecticut Agricultural Experiment Station some years since the writer was in constant receipt of questions like the following, nor have they since ceased to come:

I have a piece of old land that has been somewhat worn down by a number of years' cropping. It is such and such a kind of soil, has been treated so and so, and I want to get such a crop, and at the same time bring it into good condition. My supply of stable manure is short. Will it pay for me to try guano, or superphosphate, or potash salts? Will you be kind enough to give me a proper formula for a fertilizer for corn?

Unable, of course, to answer the inquiries I suggested some experiments by farmers for the purpose of learning which of the more costly ingredients of fertilizers were demanded by their soils and crops, and how they could be most economically supplied.

The purpose of the experiments is stated in the following extract from the report of that station for 1876:

One of the fundamental results of the vast amount of work done in field experiments with fertilizers is the clear demonstration that soils vary greatly in their capabilities of supplying food to crops, that different ingredients are deficient in different soils, and that the teachings of any given experiment are in the main applicable only to the particular kind of soil on which it is made.

For farmers who have not their own experience, or that of others in like circumstances, to guide them, the most sensible method for determining what are the deficiencies of their soils, and how they will be the most economically supplied to given crops, is to try experiments on a small scale; to put the question to the soil with different fertilizing materials and obtain its reply in the crops produced.

This is no new idea. It has been urged again and again by the leading agricultural chemists in this country and in Europe. Stoeckhardt, Knop, and Wolff, in Germany, Ville, in France, Voelcker, in England, and Johnson, in this country, have all not only urged upon farmers the importance of such experiments, but given specific suggestions for conducting them.

The report of the Connecticut Board of Agriculture for 1877 contains an account of a number of field experiments with fertilizers made in accordance with this suggestion. At the request of the American Agriculturist, plans for similar experiments, with such alterations as experience had suggested, were drawn up and proposed by that journal to its readers in the spring of 1878. At the same time the University of Vermont and State Agricultural College and the Maine State College of Agriculture and Mechanic Arts introduced similar field trials, the latter upon its own farm, the former through the agency of a number of leading farmers of Vermont. The American Agriculturist not only proposed the experiments to its readers, but, with the hearty co-operation of several prominent dealers in fertilizers, arranged to provide the materials at prices just covering the cost. With each lot of fertilizers

were sent explanations and directions for the experiments, and blanks on which such of the experimenters as might care to take the needed trouble were requested to report the results.

The experiments have been made from Maine to Kansas, and from Canada to Florida. The total number I have no definite means of learning. Between 250 to 300 reports, however, have been sent to me for examination. As an application of science to farming by practical men who get their living by the labor of their brains and hands, and who have not only found in them a means of testing the needs of their soils and the ways of supplying them, but have also, by working together on a common plan, made an important addition to the sum of our knowledge of the way in which soils furnish plant food, and plants use it, and, what seems to me of more importance, have thus been able to make their farming more a labor of the mind than the hands. The work has been, I feel, of the greatest usefulness.

In explaining the details of plans and experiments, I quote, with some alterations, from one of the reports referred to:

PURPOSE AND PLAN OF THE EXPERIMENTS.

The ostensible object of these experiments was to work upon farmers' soils. Underneath this lay, in my own thought, a deeper purpose to work upon their owners' minds. And in this regard especially, the outcome has been most gratifying.

The vast amount of work done in field experiments with fertilizers has clearly demonstrated the facts that:

1. Soils vary greatly in their capabilities of supplying food to crops. Different ingredients are deficient in different soils.

2. Soils fail to furnish enough food to crops, not so much because they have not abundant stores, as because the materials are not in available forms.

3. Deficiencies in many soils are due more to their physical condition, their texture and relations to heat and moisture, and to their lack of absorptive power, the power to hold plant food and not allow it to be leached away beyond the reach of the roots of the plants, than to their lack of plant food. Such soils want amendments first and fertilizers afterwards. Tillage improves the mechanical condition of the soil, while it also aids in rendering plant food available.

4. The chief office of fertilizers is to supply the plant food which crops need and soils fail to furnish.

5. But the indirect action of fertilizers in improving the mechanical condition of the soil, increasing its absorptive power, and rendering its stores of plant food available, is often of much more consequence than their direct action in supplying plant food. Hence cheap materials, like lime and plaster, are often more profitable than farm manures or artificial fertilizers.

6. Plants vary greatly with respect to their capabilities for gathering their food from soil and air. Hence the proper fertilizer in a given case depends upon the crop as well as upon the soil.

7. It may be regarded as pretty well settled that the only ingredients of plant food which we need to consider in commercial fertilizers are *potash, lime, magnesia, phosphoric acid, sulphuric acid, and nitrogen.* Of this list the magnesia is commonly, though not always, supplied in sufficient quantities in even "worn-out" soils. Sometimes its presence in fertilizers may be of considerable importance to crops. Sulphuric acid and lime are more often deficient, and hence one reason of the good effect so often observed from the application of lime and plaster. The remaining substances, the *phosphoric acid, nitrogen, and potash,* are the most important ingredi-

ents of our common commercial fertilizers, because of both their scarcity in the soil and their high cost. It is in supplying these that guano, phosphates, bone manures, potash salts, and most other commercial fertilizers are chiefly useful.

8. It is not good economy to pay high prices for materials which our soils may themselves furnish, but it is good economy to supply the lacking ones in the cheapest way.

9. The only way to learn what materials are proper in a given case is by observation and experiment. The rational method for determining what ingredients of plant food a soil fails to furnish in abundance, and how these lacking materials can be most economically supplied, is to put the question to the soil with different fertilizing materials and get the reply in the crops produced.

10. The results of any given experiment are, in the main, applicable only to the particular case where it is made.

11. A single season's experimenting does not tell the whole story. To get complete results the trials must be carried through a series of years and crops.

To test the needs of the soils with respect to the chief ingredients of chemical fertilizers, phosphoric acid, nitrogen, and potash was the special and the action of different fertilizing materials the general object of these experiments.

THE FERTILIZERS USED IN THE EXPERIMENTS.

Fertilizing materials were chosen which contain nitrogen, phosphoric acid, and potash, in forms shown by general experience to be appropriate and advantageous for use, to wit:

Nitrate of soda, to furnish nitrogen.

Superphosphate, to furnish phosphoric acid (with sulphuric acid and lime).

Muriate of potash, to furnish potash.

Land plaster, to furnish sulphuric acid and lime.

The several materials in small bags were put up in sets. One, called "acre set," contained ingredients as below:

FERTILIZING MATERIALS.

ACRE SET.

Bag No.	Kind.	Amount.	Valuable ingredients.	Per 100 pounds.
		Pounds.		*Per cent.*
A	Nitrate of soda	20	Nitrogen	15
B	Dissolved bone black	30	Phosphoric acid	15
C	Muriate of potash	20	Potash	50
D	Nitrate of soda	15	Nitrogen	5
	Dissolved bone black	30	Phosphoric acid	10
E	Nitrate of soda	15	Nitrogen	6.42
	Muriate of potash	20	Potash	28.57
F	Dissolved bone black	30	Phosphoric acid	9
	Muriate of potash	20	Potash	20
G	Nitrate of soda	15	Nitrogen	3.46
	Dissolved bone black	30	Phosphoric acid	6.92
	Muriate of potash	20	Potash	15.36
H	Plaster	20		

The contents of each bag of the "acre set" were intended for a plot one-tenth of an acre. The eight plots thus fertilized, with two unmanured, thus make one acre. This "acre set" was furnished for $8.30.

Another "half-acre set" contained similar materials, but in half above amounts, was also supplied at a cost of $5. The "acre-set" was most strongly recommended, and was used by the majority of experimenters. Later experience, however, has led me to question whether for ordinary farmers, the smaller experiments with plots of one-twentieth instead of one-tenth acre, are not preferable. Another outcome of the experience has been a slight modification in the quantities of the materials, and in the increase of phosphoric acid and decrease of nitrogen and potash, as will be explained later on. These sets furnished materials in amounts, and at costs per acre, as below. The costs are reckoned at market prices, with an addition of $5 per ton for freight and handling. Of course the prices fluctuate materially, so that these could not be taken as a standard:

EXPERIMENTAL FERTILIZERS.

Number of bag.	Fertilizer used.				Furnishing valuable ingredients.			
	Kind.	Pounds per acre.	At price per ton.	Cost per acre.	Kind.	Amount per cent.	Pounds per acre.	Cost per acre.
A	Nitrate of soda	200	$75 00	$7 50	Nitrogen	16.0	32.0	$7 50
B	Dissolved bone black	300	35 00	5 25	Phosphoric acid	16.0	48.0	5 25
C	Muriate of potash	200	45 00	4 50	Potash	50.0	100.0	4 50
D	Nitrate of soda	150	48 40	10 88	Nitrogen	5.3	24.0	5 63
	Dissolved bone black	300			Phosphoric acid	10.7	48.0	5 25
E	Nitrate of soda	150	58 00	10 13	Nitrogen	6.6	24.0	5 63
	Muriate of potash	200			Potash	28.6	10.0	4 50
F	Dissolved bone black	300	39 00	9 75	Phosphoric acid	9.6	48.0	5 25
	Muriate of potash	200			Potash	20.0	100.0	4 50
G	Nitrate of soda	150	47 32	15 38	Nitrogen	3.7	24.0	5 63
	Dissolved bone black	300			Phosphoric acid	7.4	48.0	5 25
	Muriate of potash	200			Potash	15.4	100.0	4 50
H	Plaster	200	8 00	80				80

The following is a reprint of a circular giving directions for the experiments:

DIRECTIONS FOR THE EXPERIMENTS.

"What is worth doing is worth doing well." You wish to learn something of value for yourself and do something that will be useful to others also. To this end, note:

The "condensed directions."—Take the slip bearing these in your pocket when you go to lay out the experiment, and read it on the ground.

The blank for report.—Look this over while the crop is growing, think what it asks for, make up your mind how to collect the facts (it will be well to get a little five-cent blank-book for notes to be made during the summer); if you can improve the plan do so, and accept thanks.

Don't say this is too much or too hard for you to do. The season is before you. You cannot use the time and mental effort, and really not a great deal of either is required, to better purpose.

EVERYTHING IN ORDER BEFORE STARTING.

1. Have your plans complete and clearly in mind, and everything ready before you start. Proper plans at the outset; uniform soil for all the experiments, and poor or

"worn-out" soils for the soil tests; plots of proper size, shape, and accurately laid out; right application of the fertilizers; good seed; careful measurement of crops; full notes of details; and careful observation of the effects of the fertilizers on succeeding crops, are essential to the best results.

SELECT UNIFORM SOIL.

2. Select soil as nearly uniform in quality as possible. There will be more or less variation in different parts of the same field at best. The less there is of this the more reliable will be the experiments. Level land should be chosen if practicable, but if it be sloping, let the plots run up and down the ascent so that any wash by rains will not transfer the materials from one plot to another. Of course the portion chosen for experiment should be a fair sample of the whole field.

"WORN-OUT" SOILS FOR SOIL TESTS.

3. For *soil tests* select poor or "worn-out" soils. You want to learn what the soil itself can do by its own natural strength, not what it will do with the aid of a store of plant food, which has been either accumulated by natural processes or left over from previous manuring, and will obscure the action of the fertilizers.

LAY OUT PLOTS ACCURATELY.

4. Lay out the whole experimental area and the individual plots as accurately as you can. Measure with chain or tape, if you have it, otherwise with pole marked in feet and inches. Drive good, strong stakes firmly into the ground at the boundaries so that you may be able to tell in this and coming seasons where the divisions are. Don't let the stakes get knocked over or plowed up.

LONG NARROW PLOTS.

5. Make the plots as long as practicable, so as to compensate as far as possible for the unevenness of the soil. To this end let the whole area be as long and narrow as convenient, and the plots run lengthwise through it. If the seed is to be planted in rows the length can be adapted to the distance of the rows apart. If this space is less than two and one-half feet an unmanured row had better be left between each two strips. In general, an unmanured strip at least two or three feet wide should be left between each two plots, so as to prevent the crop of one from being affected by the manure of another.*

If the soil is even, small, short plots will do. But generally it will not be even, and long strips are therefore safer. A good plan is to have *the whole area six times as long as it is wide.* For an area of one acre, 32 by 5 rods (= 160 rods) will make the length just about six times the width. The ten plots of one-tenth acre would thus be each 32 rods by $\frac{1}{2}$ rod. See "condensed directions" for figures for calculating dimensions of plots.

FERTILIZERS WELL DIFFUSED THROUGH SOIL.

6. The fertilizers may be applied broadcast, or if more convenient, they may be put in the hill or drill, *provided they are well diffused through the soil.* To accomplish this, they had better be diluted with several times their bulk of earth before using. The important points are, that they be:

1st. Applied evenly over the plots where they belong and not allowed to get outside.

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*With corn, either leave one unmanured row between each two plots or cultivate between the rows deep enough to cut the roots and prevent them from feeding on their neighbors' fertilizers. This "intercultural tillage" will do no harm and may be a decided benefit.

2d. Well distributed through the soil.

Experiments with concentrated fertilizers are often spoiled, just as crops are injured or lost through wrong application. Farmers are apt to think the manure must be put close to the seed or the plant will not get the benefit of it. This is wrong. It is not the just germinated plantlet that needs the manure, but the plant, from the time it is well started until its growth is done. We want, not only to give the crop a good start, but to help it out on the home stretch as well. The roots and their branching rootlets run out in all directions in search of food, and the fertilizers ought to be where as many of the rootlets as possible can get at them. If we distribute the fertilizers as well as we can, the water in the soil, aided by the chemical and physical forces that nature keeps in operation, will do the rest. In illustration of this, remember how well barn-manure acts when applied as a top-dressing long before the seed is put in.

But if we concentrate the fertilizers in one place, fewer roots will get them, and these may be injured by coming in contact with them or with their concentrated solutions in the soil. The roots will find their way to the manure and develop more where it lies, it is true; still we should not oblige them to huddle together in one place, but should rather encourage them to spread around, where, with the increased capacity the fertilizer gives them, they can get the more from the soil. Roots join with other natural agents in rendering inert stores of plant food available.

Above all, do not let the fertilizers come too close to the seed. A coarse, dilute material like yard manure may do the plants no harm, but such concentrated fertilizers as potash salts, dried blood, or high grade superphosphates may kill them.

Since, in these experiments, it is particularly important that the effect of each fertilizer be fairly tested, it would be well to *mix them with three or four times their bulk of mellow earth before applying*. If the latter is rich in vegetable mold, so much the better. Moist sawdust may be used in place of the earth, if more convenient. Do this by all means if applied in the hill or drill. It will be well to even off the ground by a shallow plowing, spread the fertilizers evenly over the plots, and then work them in with a good, deep-running harrow, or turn them under by very shallow plowing. When the plots are accurately staked out and the fertilizers carefully applied and worked in, the plow or harrow may be run across the plots without fear of transporting the fertilizers from one to another. Apply as long as possible before planting.

UNMANURED PLOTS FOR COMPARISON.

7. It is of the greatest importance that several unmanured plots be left for comparison. For eight manured plots, two unmanured will suffice; but where there are more than that, three, one at each side and the one in the middle, or, if the number is large, one in the middle and one half-way between this and each side would be advisable. You will have very little idea how uneven an apparently uniform soil may be until you make the trial.

OTHER FERTILIZERS TO BE TRIED.

8. It will be well to try other materials along with the experimental, &c. Guano, fish, ashes, farm-manures, and especially *lime* are to be recommended.

ARRANGEMENT OF PLOTS.

9. Arrangements like the following will be well:

Regular set.			Regular set and extras.		
Plot No.	Bag No.	Fertilizers.	Plot No.	Bag No.	Fertilizers.
0.	.....	No manure.	0.	.....	No manure.
A.	A.	Nitrogen.	A.	A.	Nitrogen.
B.	B.	Phosphoric acid.	B.	B.	Phosphoric acid.
C.	C.	Potash.	C.	C.	Potash.
D.	D.	Nitrogen and phosphoric acid.	D.	D.	Nitrogen and phosphoric acid.
E.	E.	Nitrogen and potash.	E.	E.	Nitrogen and potash.
F.	F.	Phosphoric acid, and potash.	00.	.....	No manure.
G.	G.	Nitrogen, phosphoric acid, and potash.	F.	F.	Phosphoric acid and potash.
H.	H.	Plaster.	G.	G.	Nitrogen, phosphoric acid, and potash.
00.	00.	No manure.	H.	H.	Plaster.
			K.	.....	Wood ashes.
			L.	.....	Lime, freshly slaked, 60–75 lbs. on $\frac{1}{10}$ acre.
			M.	.....	Farm manure.
			000.	.....	No manure.

SEE THAT ALL IS DONE RIGHTLY.

10. Attend to the work yourself. Don't trust it to the hired man unless you are sure he will do it better than you can.

MAKE ACCURATE OBSERVATIONS.

11. Watch the experiments closely. Note your observations. Make them both as accurate and complete as you can. Put down your notes when you make your observations. Do not trust them to future recollection.

REPORTS.

12. Make your reports as full and accurate as possible. Keep one copy for your own future use, and send the other in so that your results may be compared and published with others in good season. The benefit will not be yours alone, but you will share with others the good that will come from the combined work of all.

THIS PROGRAMME IS NOT AS DIFFICULT AS IT SEEMS.

This may seem a pretty heavy programme fot ordinary farmers. If you cannot follow the directions fully, come as near to them as you can. Of course the circumstances in which you work will require changes which your own good judgment will regulate.

A briefer set of directions was also supplied, as follows:

CONDENSED DIRECTIONS.

1st. Have your plans all made and everything ready before you start. Remember that poor soil for the soil tests, uniform soil for all, plots long and narrow and accurately measured and staked out, and right application of the fertilizers are essential to the best success. Don't forget the tape or pole for measuring, the stakes, and the earth for diluting the fertilizers if they are to be put in the hill or drill.

2d. Note on the back of this the dimensions you have determined upon for the whole field and for each plot.

3d. Select a fair average portion of the field to be tested, lay it out as accurately as you can, and put strong stakes firmly into the ground at the boundaries.

4th. Designate each plot by a number, A, B, C, &c., corresponding to the number of the fertilizer. Put a stake opposite each and tie a label to it with the number of the plot and kind of fertilizer. The tags on the bags will serve for labels.

5th. Distribute each fertilizer evenly over its plot, and do not let it get outside. Lay your plans for doing this in advance, otherwise you may find the fertilizer all used up before you get to the end, or have some left over. Remember what was said about mixing well with the soil, especially when put in the hill. If you do not you may kill some of the seed and injure the growth of the rest.

6th. Be as systematic and accurate as you can, not only in starting the experiments, but in carrying them out, and noting the results.

A long, narrow, experimental area, divided lengthwise in narrow strips. A good rule is to have the whole area six times as long as it is wide, or as near this as practicable.

ONE-TENTH ACRE PLOTS—LENGTH AND WIDTH.

To calculate size of plot of one-tenth acre (for "acre set") find in the left-hand column "width" the figure for the width you have decided upon, the opposite figure in the right-hand column will represent the length; or, given the length in the right-hand column, the opposite figure in the left-hand column will be the width. For one-twentieth acre plots ("half-acre set") take of course half the length for same width, or *vice versa*.

Width.	Length.	Width.	Length.
Rods.	*Feet* = *Rods.* *Feet.*	*Rods.*	*Feet* = *Rods.* *Feet.*
One-third	792 = 48	Two-thirds	396 = 24
Two-fifths	660 = 40	Three-fourths	352 = 21 5½
One-half	528 = 32	Four-fifths	330 = 20
Three-fifths	440 = 26 11	One	264 = 16
Feet.	*Feet* = *Rods.* *Feet.*	*Feet.*	*Feet* = *Rods.* *Feet.*
6	726 = 44	11½	379 = 23
6½	670 = 40 10	12	363 = 22
7	623 = 37 12	12½	349 = 21 2
7½	581 = 35 3	13	335 = 20 5
8	545 = 33	13½	323 = 19 9
8½	513 = 31 1	14	311 = 18 14
9	484 = 29 5	14½	300 = 18 3
9½	459 = 27 13	15	290 = 17 10
10	436 = 26 7	15½	281 = 17
10½	415 = 25 2	16	272 = 16 8
11	396 = 24	16½	264 = 16

For an area of one acre, 160 square rods; 5 by 32 rods will be good dimensions. This will make ten plots 32 by ½ rods=16 square rods.

Note here:

	Feet = Rods. Feet.
Length of the whole area (and of each plot)	—— = —— ——
Width of the whole area	—— = —— ——
Width of each plot	—— = —— ——

THE REPORTS AND THEIR VALUE.

For reports of the results of experiments blanks were sent to the experimenters, which they were requested, if so inclined, to fill out and return. The blanks were sheets of paper about 12 by 19 inches, with space for noting on one side description of soil, subsoil, &c.; previous treatment, manuring, and yield; weather during experiment; fertilizers, and how applied; method of sowing, planting, tillage, &c.; and other details and remarks. The other side was devoted to details of

size of plots, dates of planting and harvesting, amounts, quality, value of produce in grain, roots, tubers, stalks, &c., by pounds bushels; calculated profit or loss, &c.

It has been a matter of surprise and gratification to me, not that so many of the experimenters should have made reports, but the reports should have been made so well. Some of those rec are brief, most are well filled, and many entirely so, while several additional interesting and suggestive statements covering a numb pages, for which there was not room on the blanks.

I have attempted herewith to reproduce, as faithfully as the pri conditions will allow, one of these reports—that of an experiment corn, by Mr. W. C. ATWOOD, of Watertown, Conn. Mr. Atwood's mates of values of produce are much larger than would be p in many places, but are doubtless quite correct for his season region.

WHAT THE REPORTS SAY—FAILURES AND SUCCESSES.

Many of the reports have no decided story to tell, and some no all, except failure everywhere. Some were on land so rich that th tion of the fertilizers was obscured by the stores of plant food i soil; others on soil seemingly in such physical condition that no ficial supply of plant food could make it fertile. The many vicissi to which farming is subject affected the growth in these, as in ge cultivation. Crows, cows, cut-worms, grubs, and potato beetles wo the injury and ruin of many; frosts, heat, and drought that of more. Oftentimes the failure seemed to be due to the improper duct of the experiment. The fertilizers were often applied so clo the seed as to injure or destroy the crop; but the most serious diffi of all, I think, has been found in the unevenness of the soil. F that seemed to be uniform, proved very variable. The plots one side were sometimes drier than on the other; or one plot wa old sod ground and another had been lately cultivated, and showe effects of previous manuring; while some were irregular for re upon which neither the experimenters nor the reports throw any Some of the trials were made in ways which, though meeting th thor's wishes and eminently useful for their purpose, do not adm tabulation. Some are defective in such ways as to impair or de their value.

The fact is, that these experiments are subject to all the natural vi tudes of ordinary farming, and a good many others besides, that from lack of care, experience, or understanding how to make the of patience in their execution.

But on the whole I may say that the general character of the as evidenced by the report, has seemed to me to indicate a surpr and most gratifying amount of intelligence, thoughtfulness, and tific spirit. Indeed, there is here a most forcible illustration o

D

WEAT

ch month and se
e plowed until Ma
rest of month warm
le for corn. Occas
cooler. One good
ment of corn crop.
er of the season?—

FERT

nd 8 to 12 inches
to cover a strip 12
g over the ground t
cure the marks and
drills closer togethe

METHOD OF S

ut 4 inches deep w
rel and stubble stil
aid out the plots.
rts, but thinned in
d and hoed three tim

OTHE

for some reason u
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unmanured plots, a
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such land as I have

ble manure and 10
ut $350, I obtaine
ls of potatoes; sec

other details, give w

Kind of crop: *Early Oa*
Sept. 10*th.*

COLUMN NO. 1.—As the bags
stable manure, &c., &c.
This makes the order of p

COLUMNS NOS. 2 and 3.—If th
exact amount used on each

COLUMNS NOS. 4 and 5.—Desi
guishing between the qual
4, or by measurement, in
very useful to determine w

COLUMN NO. 6.—It will be ver
have stalks well cured, if

Pounds allowed for bush

1	2
	FERTILIZER
No. of plot.	Kind.
0	Nothing .....
A	Nitrate of soda
B	Superphosphate .....
C	Muriate of potash ....
D	Nitrate of soda ..... Superphosphate .....
00	Nothing .....
E	Nitrate of soda ..... Muriate of potash ....
F	Dissolved bone-black Muriate of potash ...
G	Nitrate of soda ..... Superphosphate ..... Muriate of potash ...
H	Plaster .....
K	..... (1) .....
L	..... (2) .....
M	*Lime* (3) .....
N	.....
O	*Manure* (4) .....
000	*Nothing* .....

(1.) *Compost: Night-soil,*
they had only 15 *lbs. of nitrate*

‹. If in hills, distance from hill to hill, . Date of planting: *May 19th.* Date of harvesting:

pounds, or pounds from bushels, or shelled corn from corn in the ear, be particular to make due
ed corn in the ear may make a bushel of shelled corn, while, if the ears were weighed just after
nake a bushel. So two bushels of good ears may make a bushel or more of shelled corn, while two
f a bushel. And a measured bushel of shelled corn may weigh 56 lbs., or it may weigh 60 lbs. The
y, quality, and value of the crop. Give below your figures for pounds per bushel, &c., and other
tions.

nmanured plots and substract from that of each unmanured plot.

g your figures for cost of fertilizers and applying, and valuations of products below. The follow-
bly not be far out of the way: **A**, $8.00; **B**, $5.25; **C**, $4.50; **D**, $11.62½; **E**, $10.87½; **F**, $9.75; **G**,
oose, and tell why.

gh they will be very interesting. Columns **1** to **9** are most important.

s. ears, as my crop is about half cured. I estimate 3,000 *lbs. of stalks per ton of dry fodder.*

Appearance during growth.		Appearance and quality of produce.
· loss ere.		
. . . . .		**000.** *Unsound nubbins.*
-1. 13		**A.** " "
9. 99		**B.** *Better.*
12. 58		**C.** *Fair quality.*
21. 68		**D.** *Much better, sound.*
. . . . .	*July* 10, **G** *taking lead.* **F** *good color, hard after* **G.**	
11. 43	**000** *not so good color.* **00** *much the same as* **H.** **O**	**E.** *Much better, sound.*
21. 08	*looks finely, close upon* **G.** *Barn-yard the best. Aug.* 15, *no great difference between* **O** *and* **G** *and barn-yard. Sept.* 1*st*, **G** *will ripen earliest,* **O** *next, while* **B Y** *will give the most foliage,* **000** *and* **H** *as well as* **H** *and lime will yield but little grain, and less though much better fodder.*	**F.** *Much better, sound.*
46. 35		**G.** *Excellent grain.*
2. 25		**H.** *Unripe and poor.*
40. 12		**K.** *Sound, ripe, and good.*
11. 64		**L.** *Sound, ripe, but small.*
3. 96		**M.** *Unripe and poor.*
42. 17		**N.** *Very good and sound.*
-1. 98		**O.** *Best of all.*
. . . . .		

yard manure, 15 cords per acre. (5.) **D**, **E**, **F**, *and* **G**, *were mixtures of* **A**, **B**. *and* **C**, *except tha*

truth that among our farmers there is an amount of intelligence and ability which is not appreciated either by themselves or by the community at large, but which is capable of making, indeed is making, a very rapid advance in the intellectual character of our agriculture.

The main results of the general experiments are set forth in Tables IV to XI of the appendix. In lack of place for giving all of the details of the reports, an attempt is made to tabulate some of the principal data with the figures for produce.

TABULAR STATEMENTS OF RESULTS OF THE EXPERIMENTS.

Concerning the arrangement of these tables, the following remarks may be made:

1. The figures given by the experimenters are complete in all cases except a very few, in which minor mistakes were apparent.

2. In some cases the materials were applied in areas different from those recommended. The variations thus made in the amounts per acre, though considerable in some cases, do not affect the general result, when all are averaged together.

3. The estimates for pounds per bushel of corn and potatoes vary considerably. Corn was generally weighed in the ear, and the shelled corn computed, the different experimenters allowing from 70 to 80 pounds of ears for one bushel of shelled corn. Where the ears were measured, 2 bushels are generally reckoned equal to 1 of shelled corn. I am inclined to think that generally too little allowance was made for the shrinkage that comes in curing. It is evident that the poorer yields appear to an unfair advantage in this way, unless the different qualities of produce are sorted. With corn, for instance, the small yields—those on the unmanured plots and with inefficient fertilizers—would have much larger proportions of poor corn than the good yields. A bushel, or 75 pounds of poor ears, would give less shelled corn than the same amount of good corn. The small errors thus introduced in the tables appear to the advantage of the poorer fertilizers in the comparison.

I suppose that but few of the gentlemen whose reports are before me are used to accurate experimenting, and there are doubtless many sources of error in their work which experience in methods of accurate research and more adequate appliances would have eliminated. Several in particular occur to me. One, as above said, is that the statements of results of weighings and measurements often fail to make due allowance for the quality of the crop. Another is the lack, in the majority of the cases, of unmanured spaces between the plots to prevent the roots of one from feeding upon the fertilizers of the other. Another is the unevenness of the soil, and a fourth, improper application of the fertilizers.

For that matter, I can see many imperfections in this method of experimenting. But if we work in the right spirit, experience will be our best teacher, and our errors our most effective lessons. Indeed it seems

to me that these trials are only the beginning of what may be developed into work of the greatest value.

GENERAL AVERAGES OF EXPERIMENTS.

The following tables will be interesting—the former giving averages of results, the latter giving results of experiments which were repeated from year to year:

Averages of results of experiments of 1878, 1879, 1880, *and* 1881.

Products.	Kinds and amounts of fertilizing materials applied per acre.	O. No manure.	A. Nitrate of soda, 200 pounds.	B. Dissolved bone-black, 300 pounds.	C. Muriate of potash, 200 pounds.	D. Nitrate of soda, 150 pounds. Dissolved bone-black, 300 pounds.	E. Nitrate of soda, 150 pounds. Muriate of potash, 200 pounds.	F. Dissolved bone-black, 300 pounds. Muriate of potash, 200 pounds.	G. Nitrate of soda, 150 pounds. Dissolved bone-black, 300 pounds. Muriate of potash, 200 pounds.	H. Plaster, 200 pounds.	Farm manures.
	AVERAGE PRODUCE PER ACRE.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Corn	27 experiments in 1878	24.6	30.4	33.5	32.3	29.1	39.6	42.9	48.6	28.9	45.9
	26 experiments in 1879	24.0	30.3	36.9	33.2	38.6	34.7	40.1	46.7	29.1	43.2
	20 experiments in 1880	32.1	35.2	43.2	37.1	46.8	40.3	47.5	48.1	39.8	46.6
	7 experiments in 1881	24.2	28.8	28.7	30.3	33.5	29.2	35.3	37.1	.....	.....
	80 experiments in 1878–'81	26.2	31.4	36.6	34.0	40.3	37.2	42.5	46.8	.....	.....
Potatoes	9 experiments in 1878	100.0	103.0	123.4	129.6	143.2	106.9	153.4	177.3	106.0	132.9
	9 experiments in 1879	58.2	76.4	90.7	86.5	96.3	84.7	123.0	143.6	69.3	131.6
	4 experiments in 1880	76.3	89.3	98.2	86.7	105.8	99.4	125.0	135.3	97.9	101.3
	3 experiments in 1881	28.2	44.2	43.7	39.7	54.4	41.9	59.5	57.7	.....	.....
	25 experiments in 1878–'81	72.5	83.2	96.0	96.4	109.6	89.6	130.6	147.7	.....	.....
	Average of the experiments of 1878, 1879, and 1880, in which farm manures were used:										
	Corn, 43 experiments:										
	Average produce	24.8	30.2	34.0	33.0	40.6	35.1	41.8	47.7	26.3	45.3
	Average increase	.....	5.4	10.1	13.2	15.8	.3	17.0	22.9	1.5	20.5
	Potatoes, 15 experiments:										
	Average produce	72.1	80.2	95.0	103.3	112.4	87.7	128.9	154.6	84.1	130.1
	Average increase	.....	8.1	22.9	31.2	40.3	15.6	56.8	82.5	12.0	58.0
Sweet potatoes	5 experiments	71.2	133.9	102.3	164.3	124.5	195.2	164.9	214.2	(80.0)	272.7
Turnips	3 experiments	.....	425.0	416.7	387.7	477.0	454.0	480.7	601.0	412.0	440.0
Sugar beets	1 experiment	785	1,013	1,174	851	1,116	968	1,091	1,119.0	961	.....
Onions	1 experiment	290	580	510	680	620	500	650	610	400	380
Oats	4 experiments	21.6	25.0	36.1	22.6	47.7	38.1	30.2	41.5	.....	.....
Cotton	1 experiment	567	865	1,162	564	1,509	983	1,219	1,541	.....	.....
Clover	1 experiment	499	700	1,200	949	1,080	560	1,140	1,200	.....	.....

Averages of results of experiments, &c.—Continued.

Products.	Kinds and amounts of fertilizing materials applied per acre.	O	A	B	C	D	E	F	G	H	
		No manure.	Nitrate of soda, 200 pounds.	Dissolved bone-black, 300 pounds.	Muriate of potash, 200 pounds.	Nitrate of soda, 150 pounds. Dissolved bone-black, 300 pounds.	Nitrate of soda, 150 pounds. Muriate of potash, 200 pounds.	Dissolved bone-black, 300 pounds. Muriate of potash, 200 pounds.	Nitrate of soda, 150 pounds. Dissolved bone-black, 300 pounds. Muriate of potash, 200 pounds.	Plaster, 200 pounds.	Farm manures.
	AVERAGE INCREASE PER ACRE.										
Corn	80 experiments	.....	5.2	10.4	7.8	14.1	11.0	16.3	20.6	.....	.....
Potatoes	25 experiments	.....	9.3	25.5	23.9	37.1	17.1	58.3	75.2	.....	.....
Oats	4 experiments	.....	3.4	14.5	1.0	26.1	16.5	8.6	19.9	.....	.....
Sweet potatoes	5 experiments	.....	59.4	27.8	89.8	50.0	120.7	90.2	139.7	—14.5	198.2
Turnips	3 experiments	.....	220.4	212.1	183.1	273.4	249.4	285.1	396.4	207.4	235.4
Sugar beets	1 experiment	.....	218	379	56	321	193	294	323	164	.....
Onions	1 experiment	.....	240	220	390	330	210	360	320	110	100
Cotton	1 experiment	.....	278	575	23	1,012	345	652	954	.....	.....
Clover	1 experiment	.....	220	720	460	600	80	660	720	.....	.....

Repetitions of experiments, 1878, 1879, 1880, and 1881.

Names.	Number of plot.			O.	A.	B.	C.	D.	E.	F.	G.	H.	
	Fertilizing materials.			No manure.	Nitrate of soda.	Superphosphate.	Muriate of potash.	Nitrate of soda. Superphosphate.	Nitrate of soda. Muriate of potash.	Superphosphate. Muriate of potash.	Nitrate of soda. Superphosphate. Muriate of potash.	Plaster.	Farm manure.
Prof. J. R. Farrington	Corn repeated on same plots in 1879.	1878, Corn ..... bushels.		20.3	19.3	29.1	32.9	37.0	42.9	39.0	39.8	.....	34.8
Prof. W. H. Jordan	Three crops of 1878 side by side in one experiment. In 1879 experiment repeated with potatoes; same fertilizers on same plots.	1878,	Beans ..... pounds	540.0	660.0	630.0	765.0	690.0	990.0	600.0	750.0	540.0	810.0
			Corn ..... bushels	38.5	44.5	42.0	63.0	62.0	69.0	42.5	58.0	40.0	68.5
			Rutabaga ... bushels	225.0	285.0	315.0	240.0	428.0	203.0	413.0	518.0	263.0	300.0
		1879,	Potatoes .. bushels	37.0	49.0	38.0	73.0	47.0	59.0	111.0	129.0	35.0	116.0
Prof. W. H. Jordan	Experiment of 1880, on land contiguous to that of previous ones.	1880,	Corn ..... bushels	9.6	9.8	21.1	14.1	30.0	13.0	20.0	16.5	.....	.....
W. I. Bartholomew, Connecticut	Experiments of 1878, on different parts of same field. Experiments of 1879, side by side on land adjoining corn experiments of 1878.	1878,	Corn ..... bushels	17.7	18.7	39.9	19.1	41.9	21.1	43.1	51.7	.....	49.8
		1878,	Potatoes .. bushels	130.0	162.0	200.0	125.0	210.0	.....	220.0	250.0	150.0	.....
		1879,	Corn ..... bushels	7.7	7.4	36.5	7.7	41.4	7.1	42.0	45.7	.....	36.0
			Potatoes .... bushels	38.0	32.0	62.0	33.0	96.0	42.0	98.0	109.0	.....	36.0
	Experiments of 1880, 1881. Continuation of those of 1879 with same fertilizers, and crops on same plots.	1880,	Corn ..... bushels.	30.	20.1	43.2	24.7	45.1	24.0	52.8	50.0	.....	.....
			Potatoes .... bushels.	70.	90.0	112.0	116.0	132.0	106.0	102.0	152.0	.....	.....
		1881,	Corn .... bushels.	9.9	5.8	12.4	10.0	16.7	5.5	25.2	28.8	.....	.....
			Potatoes .. bushels.	44.0	48.9	58.0	50.0	58.0	52.0	74.0	100.0	.....	.....
Dr. H. A. Cutting, Vermont	Same fertilizers on same plots both seasons.	1878,	Potatoes .... bushels.	30.0	40.0	80.0	20.0	100.0	60.0	100.0	140.0	60.0	80.0
		1879,	Oats ..... bushels	15.6	15.3	45.6	10.0	58.7	54.4	28.1	40.0	27.8	26.9
S. H. Rising, Vermont	Same fertilizers on same plots both seasons.	1878,	Corn ..... bushels	27.5	51.9	40.0	49.1	47.1	52.4	47.7	58.7	40.0	52.6
		1879,	Potatoes .... bushels	80.0	105.0	110.0	175.0	94.0	125.0	80.0	145.0	90.0	120.0
C. Sage, Connecticut	Contiguous fields of same farm, similar soil.	1878,	Corn ..... bushels	11.3	21.5	16.5	62.3	11.2	68.9	70.3	84.0	.....	43.8
		1879'	Corn ..... bushels.	42.0	49.2	46.0	59.0	41.1	58.0	63.4	60.8	.....	.....
J. J. Dearing Georgia	Different fields	1878,	Corn ..... bushels	5.5	7.5	10.7	7.8	18.4	.....	14.5	18.5	9.4	.....
		1878,	Cotton ..... pounds.	104.5	38.5	242.0	66.0	599.5	.....	457.0	693.0	44.0	.....
		1879,	Cotton ..... pounds	.....	.....	.....	.....	1,204.0	819.0	1,035.0	1,023.0	.....	.....
C. Miller & Son, Vermont	Different fields	1878,	Corn ..... bushels.	20.2	40.5	57.2	30.0	67.9	.....	71.0	70.5	23.0	60.0
		1879,	Corn ..... bushels	21.9	27.5	33.7	23.7	30.6	31.2	28.7	38.7	34.7	.....
Edward Hicks, Long Island	Different fields	1878,	Corn ..... bushels.	49.2	60.0	54.0	37.8	54.3	.....	57.3	76.0	48.3	66.8
		1879,	Corn ..... bushels.	32.5	53.3	54.5	59.6	69.6	82.2	76.5	82.7	58.7	55.3
		1880,	Corn ..... bushels.	54.3	50.3	60.4	67.8	60.3	72.0	76.0	70.0	.....	.....
		1881,	Corn ..... bushels.	16.3	26.0	22.8	34.5	24.3	29.5	28.2	28.7	.....	.....

Repititions of experiments, &c.—Continued.

Names.	Number of plot / Fertilizing materials			O.	A.	B.	C.	D.	E.	F.	G.	H.	
				No manure.	Nitrate of soda.	Superphosphate.	Muriate of potash.	Nitrate of soda. Superphosphate.	Nitrate of soda. Muriate of potash.	Superphosphate. Muriate of potash.	Nitrate of soda. Superphosphate. Muriate of potash.	Plaster.	Farm manure.
Buel Landon, Veemout	Different fields	1878, Corn ..... bushels		7.0	17.5	10.3	9.2	16.5	15.0	18.6	13.5	14.4	48.6
		1879, Corn ..... bushels.		19.7	24.2	22.3	11.0	31.3	27.2	14.0	33.4	25.8	18.0
J. M. Manning, Massachusetts	Same fertilizers on same plots—both seasons.	1879.		11.3	11.2	16.6	11.0	18.9	10.0	13.3	15.9	4.5	23.9
		1880, ...		19.7	25.5	19.2	29.1	30.4	24.5	26.9	43.2	14.3	53.7
		1881, Clover ..... pounds.		480.0	700.0	1,200.0	940.0	1,080.0	560.0	1,140.0	1,200.0	.....	.....
J. W. Pierce, Massachusetts*	Same fertilizers on same plots both seasons.	1879, Corn ..... bushels.		3.3	2.7	12.0	6.7	12.0	5.5	13.7	13.7	3.5	39.7
		1880, Corn ..... bushels.		29.6	27.1	34.0	25.4	38.3	.....	44.8	44.8	26.7	.....

* Except that the experiment of 1880 covered only about one-half of the area of 1879, the rest being on new ground.

NOTES UPON INDIVIDUAL EXPERIMENTS.

Having thus given a general outline, and more or less specific statement the experiments in general, it will be proper now to speak of some of e details. It is a matter of regret that so much of faithful, excellent, d useful work must be expressed in so little space. Almost every port contains material worthy of especial mention; and many of the perimenters have so carried out their trials as to give them no little ientific value. To select a few for especial discussion seems injustice others likewise worthy. I am compelled to restrict the particular scussion of individual experiments, however, to a small number; and so doing, other things being equal, I choose the work of practical rmers, rather than that of agricultural colleges, because the latter sually find publication in detail elsewhere; and in the belief that one f the most useful features of these experiments is the bringing out of he talent of individual men and the showing of what ordinary farmers an do?

MR. BARTHOLEMEW'S EXPERIMENTS.

The experiments of Mr. Bartholemew were begun in the year 1877, nd have now been going on for five successive years; have covered early one hundred plots; been repeated on the same plots and with the ame fertilizers and the same crops year after year, and on other parts f the same and contiguous fields with other crops, and are decidedly he most instructive and valuable ever made to my knowledge by a rivate individual in this country. They include:

(1.) An experiment with corn, begun in 1877 and continued through ive years, with the same fertilizers and the same plots.

(2.) An experiment with potatoes, made in 1878. (See Appendix, Table V, No. 27.)

(3.) A special nitrogen experiment with corn in 1878. (Appendix, Table II, No. 13.)

(4.) A special nitrogen experiment with corn and potatoes, side by ide (Appendix, Table I, No. 13), begun in 1879 and continued until he present.

(5.) A number of other trials not reported here.

I will first refer to Mr. Bartholomew's experiments with corn, which were begun in the year 1877, and continued on the same plots until the present time.

The plots were of ten square rods each. The soil is described by Mr. Bartholemew as "hill-land, a dark loam, moist, with clayey subsoil." The field was, in 1874, an old meadow, yielding about one ton of hay per acre. In 1875 it was plowed, dressed, and planted with corn, and yielded 35 bushels per acre. In 1876 it was sowed to oats, with no additional manure, the yield being 40 bushels per acre. In 1877 experiments began with corn. The land had thus been out of grass for

three years previous to the beginning of the experiment, or, up to the present time, eight years. The seasons of 1877 and 1878 were on the whole favorable. In 1879 "the spring was late. There were some storms in July and August which beat the corn nearly flat and stripped the leaves into shreds. Frost killed the corn September 25 before it matured." In 1880 the season was hardly unfavorable; in 1881 very unfavorable to the growth of corn.

The fertilizing materials used were as follows:

No. of plot.	Fertilizers.				Furnishing valuable ingredients.			
	Kind.	Pounds per acre.	At price per ton.	Cost per acre.	Kind.	Assumed per cent.	Pounds per acre.	Cost per acre.
1	Dried blood	320	$40 00	$6 40	Nitrogen	10	32	$6 40
2	Dissolved bone-black	320	35 00	5 60	Phosphoric acid	16	51	5 60
3	Muriate of potash	320	45 00	7 20	Potash	50	160	7 20
4	Dried blood	160	37 50	6 00	Nitrogen	5	16	3 20
	Dissolved bone-black	160			Phosphoric acid	8	25⅝	2 80
5	Dried blood	106⅔	40 00	6 40	Nitrogen	3.3	10⅔	2 13
	Dissolved bone-black	106⅔			Phosphoric acid	5.3	17	1 87
	Muriate of potash	106⅔			Potash	16.7	53⅓	2 40
6	Plaster	320	10 00	1 60				

Wood ashes, dry and leached, and farm manures were likewise employed, as indicated below. A number of brands of manufactured fertilizers were also tried, with results according with those from the regular experimental fertilizers.

Plot.	Fertilizer.		Yield of shelled corn per acre in bushels.				
	Kind.	Amount per acre.	1877.	1878.	1879.	1880.	1881.
1	Dried blood	320 pounds	13.7	10.0	*	21.2	*
2	Superphosphate	320 pounds	41.6	39.8	21.7	39.3	12.8
3	Muriate of potash	320 pounds	15.5	11.0	*	17.5	*
4	Mixture I and II	160 pounds of each	38.0	35.4	22.4	37.0	11.3
5	Mixture I and II and III	106⅔ pounds of each	33.5	30.5	20.7	33.3	8.7
6	Plaster	320 pounds	19.4	11.0	*	15.0	*
0	No manure		6.2	3.0	*	13.5	*
7	Wood ashes, dry	32 bushels	34.9	30.4	*	38.8†	†
8	Wood ashes, leached	48 bushels	37.7	36.6	24.6†	37.7‡	‡
9	Hog manure	16 cart loads	41.1	46.6		37.7	15.1
10	Hen manure	20 bushels	54.9	56.7			

* Entire failure.

† Dissolved bone-black, 480 pounds per acre, instead of ashes in 1880. Nothing in 1881.

‡ Ammoniated superphosphate, 480 pounds per acre, in place of ashes in 1880. Nothing in 1881.

In speaking of the results in 1881, Mr. Bartholemew says:

The land on which these experiments have now been conducted for five successive years was also plowed the two previous years, making seven years in succession under cultivation. The soil has become very light, has washed considerably on to the adjoining meadow, and seems to have become unfitted for corn. The plot fertilized with a good cart load of farm manure has produced but little more than that with phosphate. I think the condition of the soil has become such that but little more can be learned from the effect of fertilizers upon it.

Two things are especially worthy of mention in connection with this experiment. (1.) That wherever phosphoric acid was supplied a notable increase of yield resulted, and that without the addition of phosphoric acid there was no increase of crop. Indeed, the following statements from the report of the experiments in 1877 are, with few exceptions, as necessarily with variations of season almost equally appropriate to those of each of the following years. The ashes were not analyzed. The statements regarding them are made on the very probable assumption that the composition was as ordinarily found.

(1.) In the four cases, Nos. 1, 3, 6, and 0, where phosphoric acid was not supplied, the crop failed. (2.) In every case where phosphoric acid was supplied, either alone (i. e., as superphosphate with the lime and sulphuric acid incident thereto) or with other materials in Nos. 2, 4, 5, 8, 9, and 10 the crop was good. (3.) The amounts of phosphoric acid per acre in Nos. 2, 4, and 5 were 51, 25½, and 17 pounds, respectively; the yields, 41.6, 38, and 33.5 bushels, showing a corresponding decrease. Comparisons of the amounts of phosphoric acid applied and corn produced in the other cases, of which limited space excludes details, show a similar and singularly uniform ratio between the two. This parallelism between phosphoric acid and yield runs through the plots with ashes, which contain less of the phosphoric acid, and brought less corn, and those with farm manures, which contain more and brought more. (4.) The produce with potash salt and with dried blood alone was less than on the one plot with no manure. (5.) While the crop responded uniformly to the phosphoric acid, it got little apparent benefit from the other ingredients of either the chemical fertilizers, the ashes, or the farm manure.

The main feature of the story of the first year is that of the fifth; without phosphoric acid, failure; with it, a larger or smaller yield, as more or less is used, and very little help from potash or nitrogen. But there is this addition, that phosphoric acid alone is unable to carry the crop year after year.

Another point worthy of mention is that the land has refused to produce corn in good quantities for a number of years in succession with any of the fertilizers used. This is worthy of record, especially in view of the fact that on another part of the same field corn and potatoes are being cultivated continuously with different fertilizers.

Mr. Bartholemew's special nitrogen experiment of 1878, detailed in Table I of Appendix, and experiments with potatoes in the same year, given in Table V of the Appendix, were made on a contiguous part of the same field as the ones just described. As regards the effects of phosphoric acid, potash, and nitrogen, they coincided fully with the experiment just described.

In these experiments, then, potatoes had responded to phosphoric acid, potash, and nitrogen, though phosphoric acid was by far the most effective ingredient. The corn had responded very decidedly to the phosphoric acid, and had paid but little heed to the other ingredients. Two inferences seem to be deducible from these results; first, that the soil was especially deficient in phosphoric acid; second, that corn and potatoes differ materially in the effects of the several fertilizing ingre-

dients upon their growth. The soil experimented upon seemed to be reasonably uniform; still Mr. Bartholemew felt it desirable to test the uniformity more thoroughly.

He accordingly planned an experiment in which corn and potatoes should be planted side by side, and in which intervening plots should be left between the experimental plots proper; that is, plots of one-tenth of an acre each were laid out and received the experimental fertilizers. Each one of these was divided lengthwise and half devoted to corn and the other half to potatoes. Between each two experimental plots was an intervening plot. All of the plots were treated uniformly, and thus gave a measure of the uniformity of the soil. The experiment has now been going on for three years. The table herewith is a transcript of Mr. Bartholemew's report of the results in 1881. A little study of the figures will show how uniformly the conclusions above mentioned are borne out by the whole five years' work.

Special nitrogen experiment with corn and potatoes, 1881.

By W. I. BARTHOLOMEW, *Putnam, Conn.*

No. of plot.	Kind of fertilizers.	Amount per plot.	EXPERIMENTAL PLOTS. Potatoes. Good.	Poor.	Corn, ears. Good.	Poor.	INTERVENING PLOTS. Potatoes. Good.	Poor.	EXPERIMENTAL PLOTS. Potatoes. Good.	Poor.	Corn, shelled. Good.	Poor.	INTERVENING PLOTS. Potatoes. Good.	Poor.	INCREASE OVER NO MANURE. Potatoes Total.	Corn. Total.	Potatoes. Total.	Value of increase per acre. Potatoes	Corn	Cost of fertilizers, freight, and applying per acre.	Gain or loss per acre. Potatoes.	Corn.
		Lbs.	*Bu.*	*Bu.*	*Lbs*	*Lbs.*	*Bu.*	*Bu*	*u.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*					
1		7½	1.3	1.1	10	30	4.8	1.2	26	22	2.5	6.0	96	24	4	0.5	74	$3 00	$0 25	$6 00	*$3 00	*$5 65
2	Superphosphate	15	1.7	1.2	32	22	4.4	1.5	34	24	8.0	4.4	88	30	12	4.4	86	9 00	3 08	6 00	3 00	*2 92
3	Muriate of potash	7½	1.2	1.3	20	25	4.3	1.1	24	28	5.0	5.0	86	32	2	3.0	64	1 50	1 40	3 00	*1 50	*1 60
0	Nothing	0	.8	1.4	7	28	..	...	16	28	1.7	5.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	Nitrogen mixture	7½	1.6	1.3	38	36	4.3	1.1	32	26	9.5	7.2	86	22	10	*8.7	64	7 50	0 09	12 00	*4 50	*5 90
	Superphosphate	7½																				
	Nitrogen mixture	7½																				
5	Muriate potash	15	1.3	1.3	6	20	4.4	1.2	26	26	1.5	4.0	88	24	4	2.5	66	3 00	1 75	9 00	*6 00	10 75
6	Superphosphate, Muriate potash, Mixed minerals	15 / 7½	2.7	1.0	60	40	4.4	1.2	54	20	17.2	8.0	88	24	32	17.2	68	24 00	12 04	9 00	15 00	3 04
7	Mixed minerals, as No. 6	22½	3.8	1.2	84	39	4.5	1.1	76	24	21.6	7.8	90	22	54	20.8	68	40 50	14 56	15 00	25 50	*44
	Nitrate of soda, ⅓ ration	7½																				
8	Mixed minerals	22½	3.3	1.5	69	52	4.7	1.0	66	30	12.2	10.4	94	20	44	14.6	72	33 00	10 22	21 00	12 00	*16 78
	Nitrate of soda, ⅔ ration	15																				
9	Mixed minerals	22½	3.2	1.3	82	53	4.4	1.2	64	26	8.0	10.8	88	24	42	10.8	66	31 50	7 56	27 00	4 50	20 44
	Nitrate of soda, full ration	22½																				
00	No manure	0	1.4	1.6	†21	†36	....	.	28	32	15.2	†7.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	Mixed minerals, Nitrogen mixture, ⅓ ration	22½ / 7½	4.2	1.5	96	35	5.0	1.5	84	30	24.0	7.0	100	30	62	23.0	78	46 50	16 10	15 00	31 50	1 10
11	Mixed minerals, Nitrogen mixture, ⅔ ration	22½ / 15	4.1	1.3	100	32	5.0	1.2	82	26	25.0	6.4	100	24	60	23.4	76	45 00	16 38	21 00	24 00	*4 62
12	Mixed minerals, Nitrogen mixture, Full ration	22½ / 22½	4.6	1.1	102	28	4.8	1.0	92	22	25.5	5.6	96	20	70	23.1	74	52 50	16 97	27 00	25 50	*10 93
13	Mixed minerals	22½	3.9	1.2	72	32	4.4	1.0	78	24	18.0	6.4	88	20	56	16.4	66	42 00	11 48	15 00	27 00	*3 52
	Sulphate of ammonia	7½																				
14	Mixed minerals	22½	4.3	1.2	112	28	4.1	1.2	86	24	28.0	5.6	82	24	64	25.6	60	48 00	17 92	21 00	27 00	*3 08
	Dried blood, ⅓ ration	15																				
	Peruvian guano	22½	3.8	1.3	96	30	4.4	1.0	76	26	24.0	6.0	88	20	54	22.0	66	40 50	15 40	27 00	13 50	11 60
	Muriate of potash	7½																				
6	Mixed minerals, as No. 6	22½	3.1	1.4	104	29	4.3	1.5	62	28	26.0	5.8	86	30	40	23.8	64	38 00	16 66	9 00	21 50	6 24

In all the scores of trials which Mr. Bartholemew has made, the same results have been obtained. Corn responded largely to phosphoric acid, less to nitrogen, and scarcely at all to potash; and potatoes responded to all, but chiefly to potash. It should be added, however, that Mr. Bartholemew has oftentimes got the best results by using farm manures, supplemented by superphosphates. Indeed, in his case, as in many others, the proper use of manures for fertilizers is to supplement the manures of the farm.

MR. FAIRCHILD'S EXPERIMENTS.

The experiment of Mr. Fairchild, in 1881, was given in detail above. Others may be found in Tables I and II of the Appendix. In his experiments, which have been going on now for five years, Mr. Fairchild has been seeking the solution of a number of problems, some of which may be expressed thus:

(1) Do crops on my land demand more nitrogen, phosphoric acid, potash, sulphuric acid or lime, than my soil supplies?

(2) Do different plants differ with respect to their capacities for gathering these materials for themselves, and their consequent demand for them in fertilizers?

(3) In what forms, quantities, proportions, and ways, can I use these fertilizing elements with profit?

Five years ago Mr. Fairchild began a series of experiments somewhat on the plan of the general experiments already described. The results indicated that phosphoric acid would be especially efficient, though potash and nitrogen were likewise useful. Not content, however, with this, he went into some more elaborate trials, and finally undertook some series of special nitrogen experiments, as have been detailed. Being led to this by the facts that while nitrogen seemed very beneficial, yet it was very expensive, and hence it became a matter important to him to learn how much or how little could be used with profit, in the spring of 1880 he selected a portion of an old pasture, the soil of which was very poor, and seemingly of little value. On this he laid out twenty-five plots of one-twentieth of an acre each, and applied fertilizers to obtain corn, as shown in Table I of Appendix. In 1881 he repeated the experiment, putting the same fertilizers on the same plots, but divided the experimental area in two equal parts, by a line running across the experimental strips; devoting one-half to oats and the other to potatoes. The results of this experiment are set forth in Table I of the Appendix, and in more detail as above, in the chapter on the nitrogen experiments. In the fall of 1881 the land was sown to wheat and grass, and fertilizers applied as before. After taking off the wheat of 1882, Mr. Fairchild proposes to let the land lie in grass as long as it can be made to yield well. Thus, by using the same fertilizers on the same plots year after year, through the regular rotation, Mr. Fairchild is gaining definite information as to the effect, cost, and profit of the more

expensive ingredients of the fertilizers used, particularly of the nitrogen.

Some time since Mr. Fairchild favored me with a visit at my study, and gave quite a number of details concerning the results of his experiments and experience. With his permission I made notes of some of the conversation, and on looking them over after his departure, took occasion to send him a few further questions in a letter which he has kindly answered. The observations seemed to me so correct, apposite, and valuable that I asked the privilege of putting them in print. The argument, strongly urged, that they would be very useful to his fellow farmers, finally overcame the objections which his modesty interposed. I quote as nearly as practicable his own words in the statements which follow:

* * * On the whole, phosphoric acid in superphosphate and bone, and potash in muriate, have thus far proved most efficient. At the same time, in many cases at least, I like some nitrogen also, and think a complete fertilizer is the most profitable for me.

* * * As to the outcome of my experiments with nitrogen, that depends upon soil and crops. * * * In my experience thus far, nitrogen in small quantities has generally proved profitable. Bone and potash give a moderate yield of corn and oats on very poor land, but I like a good handsome crop, and 24 pounds of nitrogen added, has more than repaid the cost in increased yield of corn and oats. That is, mixtures containing "one-third ration" of nitrogen have been uniformly more profitable than "mixed minerals" alone, or than mixed minerals with a two-thirds or a full ration of nitrogen; and this is my experience on a larger scale. * * *

Yet in a number of cases potash salts with bone, and also with superphosphate, bring excellent crops without nitrogen, and the addition of nitrogen would be unprofitable.

My neighbor, Mr. Williams, had a very fine piece of corn this year, with only 200 pounds per acre of bone dust, and 150 pounds of muriate of potash, the two costing $7 per acre. I have noted quite a number of similar cases in this district. But my land was very badly run out when I took hold of it, and seemed to demand a little nitrogen. So far as I have observed, soils that have been well manured, seeded down, kept in grass awhile, and then plowed again, do well with potash and phosphoric acid, without artificial supply of nitrogen. My corn in last year's nitrogen experiments, rose with the amount of nitrogen added, but the increase was not enough to pay the cost of the 72 pounds or even of 48 pounds, though it did pay for the 24 pounds. And with the oats on the same plots the past season the yield rose with increase of nitrogen, but the smallest quantity was the most profitable, as you can see by comparing Plot No. 7 with Nos. 8 and 9, and No. 10 with 11 and 12.

But the potatoes gave a better response to the nitrogen than the oats. With them the two-third's ration, 48 pounds per acre, was the most profitable, and the value of the increase exceeds the cost of the fertilizer. With 48 pounds of nitrogen, the gain was $57 to $65, while with either 72 pounds or 24 pounds it runs from $40 to $59. I notice also, as a result of my experiments, that the potatoes seem to respond to the potash much more readily than either oats or corn.

To my question, "Have you arrived at any formulas as most suitable for fertilizers for your crops?" Mr. Fairchild answered as follows:

Yes and no. That is, I have made up my mind what will probably do well on my land and under my conditions for some of my crops. But I cannot say what would be most advantageous elsewhere, nor do I yet know exactly what will prove best for me years hence, or with crops I have not tested. For my corn I expect to use next spring 250 pounds of fine ground bone, 150 pounds muriate of potash (containing 50

per cent. actual potash), and 24 pounds of nitrogen in the cheapest form I can get it. So far as my experiments go, they indicate that sulphate of ammonia and nitrate of soda do rather better than dried blood. Nitrate of soda is cheap now, and I rather expect to use that.

With potatoes and oats I have not experimented so much. Judging from the past season's experience, it seems probable that the quantities of bone and potash salt I just mentioned, and about double the nitrogen, will make a good mixture. For oats I am inclined to make use of the same proportions as for corn, but I think smaller total quantities would do upon these crops. According to analysis, an oat crop takes less from the soil than one of corn, and my experience indicates that oats will do well with less manure. I expected the large quantities on some of the plots of the nitrogen experiment would make them lodge badly, but the weather or something else kept them up all right.

MR. SAGE'S EXPERIMENTS.

I wish likewise to call especial attention to the experiments of Mr. Sage, detailed in Table I of Appendix, in both of which potash has proved remarkably efficient; phosphoric acid added something to the yield, but nitrogen has been almost without effect. In an experiment in another trial not reported here, Mr. Sage found very similar results.

One hundred and fifty pounds of muriate of potash made, as Mr. Sage says, the difference between a crop scarcely worth husking, and 60 bushels per acre of as fine corn as he could ask for.

MR. NEWTON'S EXPERIMENTS.

The experiments of Mr. Newton, detailed in Tables II and III, Appendix, are among the most interesting of all. The particular point in this case is the effect of nitrogen upon the corn. While in most cases the nitrogen has little or no effect, in Mr. Newton's trials it was the only effective ingredient; and the corn responded to it very uniformly wherever it was applied.

Had not so much space already been consumed, I should speak in detail of a number of other experiments; as those of Mr. Pierce, Mr. Hicks, Mr. Eliason, and others.

EXPERIMENTS OF MR. CLENDON.

I must, however, make at least brief reference to the experiments by Mr. Clendon, of Virginia, which are found in Table VIII of the Appendix. The most interesting point in Mr. Clendon's experiments is the effect of the raw or undissolved South Carolina phosphate. Concerning this, Mr. Clendon writes as follows:

Allow me to call particular attention to the benefits derived from the use of finely powdered but otherwise unmanipulated South Carolina rock. I have used it for several years in quantities varying from the single bag up to ten tons, and have become satisfied that in equal values it did as much good as the superphosphates; but until this year have not made comparative tests where the crops were weighed. * * *

It will be seen from the experiments that nitrate of soda and potash do not pay. Superphosphate of lime did well, but the South Carolina phosphate did better. An application of 400 pounds per acre gave an increase of over 19 bushels of shelled corn.

The soil is a decomposed gneiss, uniformly poor, and is a fair sample of hundreds of square miles lying between the base of the Blue Ridge and tide-water in Virginia.

On soils containing lime, superphosphate is rapidly reduced to an insoluble condition, and from its extreme fineness may be better than the raw phosphate; but judging from the softness of our spring water—for household purposes practically as soft as rain water—my soil contains very little lime, and a soluble phosphate may be positively injurious; and when not injurious may form the insoluble, inert phosphate of iron.

My experiments have been carried over ten years with uniform results. In every year the good effect of the raw phosphate was apparent. As South Carolina phosphate is so cheap, I think my experiments should be repeated over a wide country. I am aware that in some localities an insoluble phosphate is regarded as of no value. The same may be said of superphosphates. Experiment alone is the farmer's safety.

EXPERIMENTS OF PROFESSOR STUBBS.

These experiments are of especial interest from the fact of their being made with cotton, the study of which for the Southern States, is of incalculable importance. On receipt of Professor Stubbs's report, I wrote him a letter containing the following:

The results seem to me most interesting and valuable. The potash, as you say, appears to have very little effect, the nitrogen more, and the phosphoric acid most of all. In how far these results are decided by the soil and to what extent they are due to the feeding capacity of the plant are of course questions for further investigation. It is, however, interesting to note that, while the one-third nitrogen ration in each of the three nitrogen groups materially increases the yield, or at least appears to do so, instead of rising with the large applications of nitrogen, actually falls. I have put your figures together so as to show this.

Assuming the yield on Plot No. 7 with Fertilizer No. 6 to represent what would be the yield in each case with superphosphate and potash salt, we have yields of cotton and gains due to nitrogenous fertilizers as follows:

Nitrogenous fertilizer.	Amount of nitrogen.		
	24 pounds.	48 pounds.	72 pounds.
	Pounds.	*Pounds.*	*Pounds.*
Nitrate of soda	1,545	1,403	1,242
Sulphate of ammonia	1,115	1,265	1,162
Dried blood	1,357	1,300	1,127
Average of above	1,338	1,323	1,177
Mixed minerals	1,219	1,219	1,219
Gain from nitrogen	119	104	42
Cotton-seed meal	1,253	1,518	1,345
Mixed minerals	1,219	1,219	1,219
Gain from nitrogen	34	299	126

Thus in the nitrate of soda group, Nos. 8, 10, and 13, the No. 8, with 24 pounds of nitrogen per acre, shows increase of over 300 pounds over No. 6, "mixed minerals," while in Nos. 8 and 9 the amount decreases so as to show with 72 pounds of nitrogen in No. 9 no increase over No. 6. The results with the sulphate of ammonia group show practically no increase; indeed, if anything, a falling off of nitrogen. Nor are they much more favorable with dried blood; indeed here while there is a slight gain with the one-third ration, the others fall off until with the full ration there is a decided decrease as compared with the yield with no nitrogen at all.

In short one can almost say that the more nitrogen there is applied the less cotton is produced.

Of course if we had the four plots with "mixed minerals" instead of one, the comparison would be more reliable as an index of the gain with nitrogen. Still these figures agree very emphatically in testifying that the large quantities of nitrogen in the commercial forms were very unprofitable.

The figures for cotton-seed meal are striking. Lumping the gains with the several nitrogenous materials together, we have more with this than with either sulphates of ammonia or dried blood, and about the same as with nitrate of soda. Thus the total yields are:

Amount of ration.	Nitrate of soda.	Sulphate of ammonia.	Dried blood.	Cotton-seed meal.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels*
One-third ration	15.45	11.15	13.57	12.53
Two-third ration	14.03	12.65	13.00	15.18
Full ration	12.42	11.62	11.27	13.45
Sum	41.90	35.42	37.84	41.16

That is to say, according to the testimony of this experiment:

1. In return for 24 pounds of nitrogen per acre in commercial fertilizers, which would cost, near the large seaboard markets, at present prices, cash, say (24 pounds, at 25 cents per pound), $6, and in the interior, on time, a good deal more, you get, on the average, 119 pounds of cotton. When you double the amount of nitrogen you get less increase; trebling it, you have a loss.

2. But when, instead of using these imported products, you put back on your land the cotton seed it has already produced, enough to furnish the same quantity of nitrogen (about two pounds of cotton-seed meal for one of nitrate of soda, and three for one of sulphate of ammonia), you get as much as with the nitrate of soda and more than with anything else.

Of course, no wise man will proclaim a general principle from a single series of experiments. Still these results are certainly striking and suggestive. There are two questions in particular which they suggest anew to me, as doubtless they have done to you.

First. Where, how, and in what quantities can nitrogen be used with profit to grow cotton?

Second. If this element, which is already scarce and costly, and growing scarcer and costlier year by year, is necessary to make cotton grow, is it better for planters to send their money to distant dealers who must search the North, East, and West, and even send to foreign lands to obtain it, or to utilize a home product that furnishes the nutrition at vastly less cost and a lot of phosphoric acid and potash besides? The farmers and planters of Georgia and other Southern States are importing millions of dollars' worth of nitrogen every year. Is this wise, and how can the question as to the economy be solved otherwise than by direct experiment?

I have thus hastily and crudely set down some of the things that first occur to me from very brief study of your experiment. My object is not to assume the position of interpreter, but rather to inquire if these ideas agree with your own, and to ask if you will not kindly favor me with your own interpretations and suggestions. I should regard it as an especial favor if you would furnish me your comments for publication with your experiment.

To this Professor Stubbs replied as follows:

I refrained from the discussion of the result of the experiments *in extenso*, because I have discussed the questions involved in an official report now in press. In making this series of experiments I had the following questions in view:

1st. Which of the valuable ingredients of manure, nitrogen (or ammonia), phosphoric acid, and potash, are needed by cotton on our soil?

2d. Which form of nitrogen is best adapted to the requirements of cotton, the nitrogen being furnished in the form of nitrate of soda, sulphate of ammonia, dried blood, and cotton-seed meal?

3d. If nitrogen is needed, what amount is necessary to make a maximum crop at greatest profit?

Nearly all of these questions were decided to my own satisfaction by a series of carefully conducted experiments extending through five years on my plantation near this place, several years since. They have been repeatedly published, all tending to show that *our soil* results from disintegration of metamorphic rocks, principally hornblendic and feldspathic, showing—

1st. No need of potash for cotton.

2d. Decided need of phosphoric acid in soluble forms.

3d. A small advantage from nitrogen in moderate quantities.

Upon soils rich in vegetable matter, the last deduction may be amply modified, but our great want for cotton, and it seems to prevail throughout the older cotton States, is soluble phosphoric acid. On worn-out soils a small amount of nitrogen also seems to be required.

The most favorable proportion seems to be about three parts nitrogen to ten of phosphoric acid. Cotton-seed meal has been practically tested by myself alongside of other nitrogenous material, time and again, and has always proved equal in fertilizing value, and cost less than other nitrogenous fertilizers. So decided have been the results of these experiments that for four years I have not bought an ounce of manipulated guano or chemical salts, other than dissolved bone and cotton-seed meal. A mixture of these two furnishes a manure for cotton, which, I think, cannot be surpassed by any other mixture. I have found but one other equal or superior to it, and that is a compost of cotton-seed, stable manure, and dissolved bone.

In speaking further of the poor economy of purchasing nitrogenous material outside, and the better policy of using cotton-seed, Professor Stubbs continues:

Let us compare results. A fertilizer containing 3 per cent. of nitrogen and 10 per cent. of available phosphoric acid, sells here for $45 per ton cash, or for a bale of cotton on time. A fertilizer made of equal parts of a high grade of dissolved bone, costing here $30, and showing 14 or 16 per cent. of available phosphoric acid, and cotton-seed meal which, costing $20 per ton, will contain 3½ per cent. of nitrogen, and 8½ to 9½ per cent. of available phosphoric acid, and will cost $25 per ton. Hence you get nearly two tons of the latter, strictly pure, at the cost of one of former, which would be up to the standard. I use annually 20 tons of the mixture, which costs me less than $20 per ton, while my neighbor, who buys on time, pays 20 bales of cotton for the same amount, and here is the secret of failure to use cotton-seed meal in larger quantities as a manure. It sells for cash, and our cotton planters buy little or nothing that way.

Nearly all of our cotton-seed meal goes to Europe and North to be used for feeding, while both our lands and our stock cry out against this unnatural deprivation. But a change is gradually being wrought. Already a large company is operating in this State manufacturing a high grade of goods out of cotton-seed meal and a high grade of dissolved bone. But they sell on time, and will, I expect, make a large profit. So much for results of other experiments of which these are confirmatory. Now to experiments themselves. 1st. Potash gives no increase. 2d. Phosphoric acid brings decidedly good returns. 3d. Nitrogen increases the yield a little. 4th. Increase of the nitrogen is practically of little use even if not detrimental. 5th. Cotton-seed meal is decidedly the cheapest form of nitrogen. These are my conclusions from experiments. Let us discuss them.

1st. In experiment No. 4 (potash alone) the yiel d is less than No. 1 (with nothing) just the difference, I think, between the natural fertility of the two plots.

2d. Phosphoric acid increased every yield where it was used, and this has been the universal result of all experiments in cotton in North Carolina, South Carolina, Georgia, and Alabama. (In black, cretaceous prairie cotton belt of latter State fertilizers have not been used as yet, and hence this area is not included in assertion. Will try some this year on these soils to test this question.)

Phosphoric acid has the decided tendency in cotton to make fruit, so much so that in Experiments 2 and 3, until they began to fruit, no difference in appearance was perceptible. As soon as they began to take on "squares" the difference was very perceptible. Again, phosphoric acid has a decided tendency to hasten maturing, an important item here, since the caterpillar almost invariably more or less injures our late cotton.

3d and 4th. Nitrogen alone increases the crop only a little. This it does by increasing size of plant and thus enabling it to grow larger and more extended roots, by virtue of which a larger amount of phosphoric acid is gathered, which really increases the ultimate production; but the land is always overcropped thereby, and shows evidence of it the next summer. For the same reason, on most soils, a small addition of nitrogen to dissolved bone is beneficial, since its increase of roots and stalks enables the plant to utilize the phosphoric acid more completely, and perhaps also to draw an extra quantity from the soil; but if an extra amount of nitrogen is used, the organs of vegetation are developed too long into the season to admit of a large crop. This is especially true during a wet season. All the energy of the plant is exerted in making vegetation, and often the frost catches it just as it begins to fruit well. This is especially true of cotton, since it is a perennial plant, and if furnished with excess of nitrogen will continue to grow, making but little fruit, until checked by drought or cold. Farmers in rich bottom correct this tendency by topping. In this way I readily account for loss where two or three rations were used. All those experiments where two and three rations of nitrogen were used were green, growing, blooming, fruiting, and luxuriant when killed by frost. Further evidence can be found in amounts picked at various times; while nearly three-fourths of Experiments 3, 5, 7, 8, 9, 14, 17, and 22 were gathered by October 1, Nos. 10, 13, 14, 12, 16, 17, 19, and 20 not one-half and in some instances not one-third were gathered by that time. Again, with these larger rations of nitrogen, should a severe drought prevail, the plant is always burned or "rusted" to a disastrous extent, and hence loss.

Either horn of dilemma is dangerous. Extremly propitious seasons, with frost deferred till winter, only can insure a success with large quantities of nitrogen, and then only when phosphoric acid is furnished in larger quantities, either by the soil or artificially. Just here let me remark that the cotton plant is worthy of a thorough scientific study. It has a large leaf surface, endowed with power to assimilate a large quantity of nitrogen when grown on a poor soil. If, as it has been asserted, every plant is capable of assimilating the nitrogen of air in proportion to extent of leaf surface, then cotton should stand in the front rank as a "green manuring crop," and this is claimed for it by some.

In a published report of these experiments, Professor Stubbs compares in detail the effects of nitrogen in different forms and combinations as compared with its cost, and concludes as follows:

Hence the value of nitrogen in cotton-seed meal as a fertilizer for cotton is but little inferior, if not equal, to nitrogen in that form which is universally acknowledged to be the best and highest, viz., nitrate of soda. Therefore, I say with proper economy, with proper utilization of his own cotton seed, supplemented by such home-made manures (rich in nitrogen), as can be made and saved upon every plantation, the southern planter needs no imported nitrogen to grow his crops.

When we remember the proximity of the large phosphatic beds of Charleston, S. C.,

out of which are made nearly all of the superphosphates which supply our soils with that much needed ingredient, phosphoric acid; when we remember that our chief staple can be furnished with all the needed nitrogen from home sources, and that potash, when needed, can be obtained from the ashes of our extensive forests, thus furnishing from southern soil all the needful ingredients to grow our southern staple, it is with feelings of pride and pleasure that we contemplate the vast capabilities and magnificent possibilities of southern agriculture in the near future.

PENNSYLVANIA AGRICULTURAL COLLEGE—EXPERIMENTS BY PROFESSOR JORDAN.

A series of experiments, upon a plan closely according with that of the "special nitrogen experiments" above described, was instituted in 1881 upon two of the experimental farms of the Pennsylvania Agricultural College by Prof. W. H. Jordan, formerly of the Maine State College, whose experiments on the farm of the last-named institution have already been mentioned. (See Appendix Tables I and VIII.)

The following accounts of the Pennsylvania experiments are quoted from advance sheets of Professor Jordan's report for 1881, kindly furnished for the purpose:

PLAN OF THE EXPERIMENTS.

The general plan of the experiments herewith reported is as follows: The fertilizers are to be used on a rotation of crops, each rotation occupying four years. The order will be corn, oats, wheat, and grass. The fertilizers to be applied only twice during each rotation to the corn and wheat. The plots are accurately measured, and the fertilizers used and the crops produced are in each case carefully weighed. The same fertilizers are to be applied to the same plots each time, several plots not receiving any fertilizer at all. The various manures used will be phosphatic, potassic, nitrogenous, and mixtures of two or all three of these; yard manure alone and with lime; lime, ground limestone, and plaster.

The points to be given special attention are the following:

First. The necessary ingredients of a fertilizer for continued use, with especial reference to the nitrogen supply.

Second. The relative effect of the same fertilizer upon different crops.

Third. The relative effect of a continued use of commercial fertilizers and of yard manure.

Fourth. The benefits of lime, ground limestone, and plaster.

The experiments conducted the past season were with corn and oats on the central farm, and with corn on the eastern farm.

REPORT OF EXPERIMENT WITH OATS ON THE CENTRAL FARM, 1881.

Conditions of experiment.—The soil of the experimental plots on this farm is essentially a "limestone clay." It is rather tenacious and heavy when wet, but dries off rapidly after a rain, the natural drainage being good. The plots on which the oats were sown were planted to corn in 1880. Previous to that the land had grown a rotation of crops, but had received no manure for five years. In 1880 the plots all received an application of yard manure, with the exception of one or two. Although the plots had been used for experimental purposes previous to this year, the differences in the manuring was so slight in most cases, and so much time had elapsed since the application of any manure, it is believed that the results are not seriously affected by previous conditions, especially as in the past the treatment of

the plots pertained mostly to methods of plowing, and of care of the crops, rather than to radical differences in the manures used.

The size of the plots is 260 feet long by 21 feet wide, each containing one-eighth of an acre.

In the experiment on oats, the method of cultivation, time of sowing, amount of seed, and time of cutting were the same for all the plots.

The land was plowed in the spring, after which the commercial fertilizers were sown broadcast and harrowed in, the yard manure having been spread on the sod and plowed under. The lime, ground limestone, and plaster were also sown, and harrowed in after plowing. Four quarts of Excelsior oats were sown on each plot, or at the rate of two bushels per acre. The seed was sown in April 22, and the oats were cut July 18.

In the following table are shown the arrangement of the plots, the kinds and quantities of fertilizers applied per acre, the quantities of valuable ingredients contained in the fertilizers, and the yield of oats and straw per plot and per acre.

The percentages of valuable ingredients in the materials used were as follows: Dissolved bone, 16 per cent. available phosphoric acid; muriate of potash, 50 per cent. potash; dried blood, 10 per cent. nitrogen; nitrate of soda, 15 per cent. nitrogen; sulphate of ammonia, 20 per cent. nitrogen. The yard manure was that produced by fattening steers fed upon corn meal and corn fodder. It contained considerable litter.

TABLE A—*Showing results of experiment with fertilizers on oats, conducted at the central farm.*

	Number of plot.	Kind of fertilizer.	Quantity of fertilizer per acre.	Quantities of valuable ingredients applied per acre.			Production per plot.		Production per acre.	
				Nitrogen.	Phosphoric acid.	Potash.	Oats.	Straw.	Oats.	Straw.
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Bush.*	*Lbs.*
	1	Nothing					148	387	37	3,096
A.—Valuable ingredients singly.	2	Dried blood	320	32			155	485	38.7	3,880
	3	Dissolved bone	300		48		173	535	43.2	4,280
	4	Muriate of potash	200			100	172	538	40	4,304
B.—Valuable ingredients two by two.	5	Dissolved bone	300		48		177	550	44.2	4,400
		Dried blood	320	32						
	6	Muriate of potash	200			100	152	416	38	3,328
		Dried blood	320	32						
	7	Dissolved bone	300		48		150	480	37.5	3,840
		Muriate of potash	200			100				
	8	Nothing					115	300	28.8	2,400
C.—Complete fertilizer,† with nitrogen in different proportions; nitrogen furnished by dried blood.	9	Mixed minerals*			48	100	198	565	49.5	4,520
		Dried blood	240	24						
	10	Mixed minerals*			48	100	203	620	50.7	4,960
		Dried blood	480	48						
	11	Mixed minerals*			48	100	207	650	51.7	5,200
		Dried blood	720	72						
	12	Mixed minerals*			48	100	190	610	47.5	4,880
		Dried blood	240	24						
	13	Plaster	320				167	480	38.6	3,840
	14	Nothing					169	490	39.1	3,920
D.—Commercial fertilizers and yard manure compared—fertilizers as in C.	15	Mixed minerals*			48	100	206	585	51.5	4,680
	16	Yard manure	12,000	52.4	25	60.4	179	545	44.7	4,360
	17	Mixed minerals*			48	100	199	620	49.7	4,960
		Dried blood	240	24						
	18	Yard manure	16,000	72	34	83	187	565	46.7	4,520
	19	Mixed minerals*			48	100	211	710	52.7	5,680
		Dried blood	480	48						
	20	Yard manure	20,000	90	42	104	200	586	50	4,688
	21	Mixed minerals*			48	100	228	735	57	5,880
		Dried blood	720	72						
E.—Effect of lime.	22	Yard manure	12,000	52.4	25	60.4	204	600	51	4,800
		Lime	500							
	23	Lime	500				196	560	49	4,480
	24	Nothing					188	568	47	4,524
F.—Complete fertilizer,† with nitrogen in different proportions; nitrogen furnished by nitrate of soda.	25	Mixed minerals*			48	100	225	715	56.3	5,720
	26	Mixed minerals*			48	100	254	815	63.5	6,520
		Nitrate of soda	160	24						
	27	Mixed minerals*			48	100	205	715	51.3	5,720
		Nitrate of soda	320	48						
	28	Mixed minerals*			48	100	198	720	49.5	5,760
		Nitrate of soda	480	72						
G.—Complete fertilizer,† with nitrogen in different proportions; nitrogen furnished by sulphate of ammonia.	29	Mixed minerals*			48	100	248	740	62	5,920
	30	Mixed minerals*			48	100	249	772	62.5	6,176
		Sulphate of ammonia	120	24						
	31	Mixed minerals*			48	100	218	762	54.5	6,096
		Sulphate of ammonia	240	48						
	32	Mixed minerals*			48	100	229	754	57.3	6,032
		Sulphate of ammonia	360	72						
	33	Plaster	320				184	548	46	4,384
	34	Ground limestone	500				198	582	49	4,656
	35						210	680	52.5	5,440
	36	Nothing					184	652	46	5,216

*The term "mixed minerals" is used to designate the fertilizers applied to Plot 7, viz, dissolved bone, 300 pounds per acre, and muriate of potash, 200 pounds.

†A combination of dissolved bone, muriate of potash, and some nitrogenous fertilizer.

In the next table are given the average results where several plots are manured in essentially the same manner. For instance, there are four sets (C, D, F, and G of previous table) of plots in which mineral fertilizers alone (fertilizers containing phosphoric acid and potash, but no nitrogen), and the same, combined with varying quantities of nitrogen, are used, the only difference being that the nitrogen is not furnished by the same material in every set.

In order to see the effect of using no nitrogen, or of using it in small or large quantities, the average of these four sets of plots is given.

Three plots (16, 18, and 20 of previous table) were manured with barn-yard manure, and the figures given represent their average production.

It is believed that these averages represent very fairly the effect of the various fertilizers, as the plots receiving no fertilizer and those manured alike are quite well distributed over the experimental ground.

TABLE B—*Summary of Table A.*

	Kind of fertilizer.	Quantities of valuable ingredients applied per acre.			Yield per acre.		Increase over yield, with no fertilizer.		Pecuniary results.*	
		Nitrogen.	Phosphoric acid.	Potash.	Oats.	Straw.	Oats.	Straw.	Cost of fertilizer per acre.	Value of increase per acre.
		Lbs.	*Lbs.*	*Lbs.*	*Bus.*†	*Lbs.*	*Bus.*†	*Lbs.*	‡	
Average of 5 plots.	Nothing				39.6	3,830				
One plot...	Dried blood	32	..	....	38.7	3,880	—0.9	50	$7 50	
One plot...	Dissolved bone		48		43.2	4,280	3.6	450	5 25	$2 92
One plot...	Muriate of potash			100	40.	4,304	0.4	474	4 50	1 38
One plot...	Dried blood Dissolved bone	32	48		44.2	4,400	4.6	570	10 88	372
One plot...	Dried blood Muriate of potash	32		100	38	3,328	—1.6	−502	10 18	
Average of 4 plots.	Dissolved bone Muriate of potash, §		48	100	51.8	5,040	12.2	1,210	9 75	9 13
Average of 4 plots.‖	Mineral fertilizers & smallest amount of nitrogen	24	48	100	56.3	5,529	16.7	1,699	15 38	12 86
Average of 4 plots.‖	Mineral fertilizers and medium amount of nitrogen.	48	48	100	52 3	5,619	12.7	1,789	21 00	10 84
Average of 4 plots.‖	Mineral fertilizers and largest amount of nitrogen.	72	48	100	53.9	5,718	14.3	1,888	26 64	11 87
Average of 3 plots.‖	Yard manure.¶	72	34	82½	47.1	4,522	7.5	692	**8 00	5 48
Average of 2 plots.	Plaster				42.3	4,105	2.7	275	1 00	2 65
One plot...	Lime (caustic)				49	4,480	9.4	650	10 00	7 30
One plot...	Ground limestone				49	4,656	9.4	826	10 00	7 76

† Estimated on the basis of 32 pounds to the bushel.

* The oats are reckoned at $0.50 per bushel, and the straw at $5 per ton.

§ The same as "mineral fertilizers." Wherever the term "mineral fertilizers" occurs, it means 300 pounds dissolved bone and 200 pounds muriate of potash to the acre.

‖ In two sets of plots the nitrogen was furnished by dried blood, in one by nitrate of soda, and in one by sulphate of ammonia.

¶ Composition assumed to be the same as that given in Wolff's tables for fresh yard manure. The composition assumed is very nearly like that of stable manure as analyzed at the Connecticut Experiment Station.

‡ The cost of fertilizers per acre is not based upon their actual cost at the college, but upon what is a fair price at points easy of access. $5 per ton is allowed for transportation and handling.

** Based upon the cost near the college, viz., about one dollar per ton. Near cities the price would be $4 per ton, at least.

There are a few points that can be noted with profit, even in the results of one year's experiment:

1. The comparative inefficiency of the commercial fertilizers, containing but a single valuable ingredient, as the dried blood, dissolved bone, or muriate of potash.

2. The combination of phosphoric acid and potash (mineral fertilizers) caused a much better yield than either alone, and nearly as great a yield as when nitrogen was added.

3. Anything more than a small quantity of nitrogenous fertilizer, combined with the mineral fertilizers, failed to produce an increase of crop. There seemed to be no difference in this respect between the dried blood, the nitrate of soda, or the sulphate of ammonia, used to furnish the nitrogen. This failure of nitrogenous fertilizers, whether used on grain or corn, to do any better with 72 pounds of nitrogen to the acre than with 24 pounds, is in accordance with a large number of results arrived at in experiments under the direction of Prof. W. O. Atwater. (Report of Connecticut State Board of Agriculture, 1880.)

Mr. J. B. Lawes, the noted English experimenter, thinks that we fail to see marked results follow the use of nitrogenous fertilizers on grain simply because there is such a store of organic nitrogen in the soil that the plants receive sufficient supply without the aid of artificial manures. If these experiments be continued through a series of years, supplying the same plots each time with mineral fertilizers alone, and other plots with mineral fertilizers and nitrogen, the capacity of the soil and air for furnishing a continuous necessary quantity of nitrogen will be tested. It is the plan to do this on the college farms. It is certain that the crop produced by mineral fertilizers alone succeeded in getting not far from 60 pounds of nitrogen without the aid of manure of any sort. Below is a table showing the amount of nitrogen supplied by the fertilizers, the amount taken up by the crop, and the increased amount taken up because of the use of the various manures:

Kind of fertilizers.	Quantity of nitrogen supplied in the fertilizers.	Quantity of nitrogen taken up by grain and straw.	Excess of nitrogen taken up because of fertilizers of grain and straw.
	Pounds.	*Pounds.*	*Pounds.*
Nothing	.....	45.8	.....
Mineral fertilizers	.....	59.6	13.8
Mineral fertilizers and one-third quantity nitrogen	24	65.4	19.6
Mineral fertilizers and two-thirds quantity nitrogen	48	63.3	17.5
Mineral fertilizers and three-thirds quantity nitrogen	72	64.7	18.9
Yard manure	72	54	8.2

In calculating the above table it is assumed that the grain and straw have the same composition for all the plots. Probably the percentage of nitrogen is higher for those plots receiving nitrogenous fertilizers than in the others, but the difference would not be so large as to destroy the value of the above comparison.

One practical point involved in the use of nitrogenous fertilizers is that of their great cost. One pound of nitrogen costs as much as two pounds of phosphoric acid or four pounds of potash. Its presence in a commercial fertilizer in any quantity increases largely the cost of that manure. If this expense can be avoided for the present at least, it will be a great saving to the farmer.

4. The yard manure failed to produce as large a crop of either grain or straw as did the mineral fertilizers or the complete fertilizer (mineral fertilizers combined with nitrogenous).

As the manure was but little decomposed when applied, it is not strange that it failed to furnish a large amount of plant food. It is generally believed that the effect of yard manure extends over a longer period of time than that of commercial fertilizers, a large part of its benefit being felt by the second or even third crops after its application. The crops on these plots for the next few years will, probably, throw some light on this point.

5. The plaster, lime, and ground limestone did not seem to materially increase the crop over that of adjacent plots which received no manure. Neither did the ground limestone seem to possess any advantages over the burned lime.

6. None of the fertilizers paid for themselves, not even the yard manure at one dollar per load of two thousand pounds. The profits resulting from the use of the fertilizers cannot be estimated until one or perhaps two rotations are past. The land is now in pretty good condition, and is capable of nourishing a fair crop without the aid of manure, but those plots not fertilized will undoubtedly begin to show the effect of cropping after several years, whereas the plots manured will be kept up to a good standard. When that time arrives the effect of the fertilizers will be more marked.

These plots were manured exactly as for oats, and were sown to wheat in September. There is already a marked difference in the growth of the wheat on these various plots. The result will be reported in due time.

If space permitted, I should be glad to quote in detail the accounts of other experiments by Professor Jordan. It seems necessary, however, to give only a general summary.

EXPERIMENT WITH CORN ON THE CENTRAL FARM, 1881.

Conditions of experiment.—The kind of soil, previous treatment, size of plots, and method of application of fertilizers, were, as in the experiment on oats above described, "only in the case of the plots used for the corn there had been no manure of any kind applied to the land for five years. The plots which were in a partial clover sod were plowed in the spring, a short time before planting the corn." The fertilizers were the same and applied in exactly the same order as in the oat experiment.

"The growth of the crop was checked by the drought, extending through July, August, and September. At no time during the season could any difference be seen in the development of the corn on the various plots, either as to quantity of growth or in any other particular."

The following table gives a summary of results, as was done in Table B with results of experiments with oats:

TABLE C.—*Summary of experiment with corn.*

	Kind of fertilizer.	Quantities of valuable ingredients applied per acre.			Yield per acre.		Increase over yield with no fertilizers.	
		Nitrogen.	Phosphoric acid.	Potash.	Corn.	Stover.	Corn.	Stover.
		Lbs.	*Lbs.*	*Lbs.*	*Bus.*	*Lbs.*	*Bus.**	*Lbs.*
Average of 5 plots	Nothing	.....	.....	.....	33	2,373	.....	.....
One plot	Dried blood	32	.....	.....	34.7	2,576	1.7	203
One plot	Dissolved bone	.....	48	.....	35.2	2,480	2.2	107
One plot	Muriate of potash	.....	.....	100	35.7	2,640	2.7	267
One plot	Dried blood, dissolved bone.	.....	48	100	37.8	2,440	4.8	67
One plot	Dried blood, muriate of potash.	32	.....	100	35.2	2,800	2.2	427
Average of 5 plots	Dissolved bone, muriate of potash. †	.....	48	100	35	2,292	2	—81
Average of 4 plots	Mineral fertilizers, and smallest amount nitrogen.	24	48	100	34.5	2,248	1.5	—125
Average of 4 plots	Mineral fertilizers, and medium amount nitrogen.	48	48	100	32.9	2,224	.....	—149
Average of 4 plots	Mineral fertilizers, and largest amount nitrogen.	72	48	100	30.1	2,230	—2.9	—143
Average of 3 plots	Yard manure	72	34	83	37.7	2,208	4.7	—165
Average of 2 plots	Plaster	.....	.....	.....	31.8	2,260	—1.2	—113

* Shelled corn.

† Same as "mineral fertilizers."

EXPERIMENTS WITH CORN, EASTERN EXPERIMENTAL FARM, 1881.

The following experiment, also reported by Professor Jordan, was conducted by Mr. J. Fremont Hickman, superintendent Eastern Experimental Farm, West Grove, Pa. The plan, it will be noticed, is essentially similar to that of the nitrogen experiments described above. (See Table III in appendix.)

The plots upon which the experiments were made were of equal size, viz., one-twentieth of an acre each. The ground was a sod of three years' standing, without having received fertilizers of any kind.

Mr. Hickman's observations regarding growth and appearance of the corn, and the temperature and rain-fall, are so much to the point that I quote them in full:

OBSERVATIONS.—During the growth of these plots careful observations were taken every two weeks. Previous to the first of July no appreciable difference could be detected in their general appearance, but from that time on until the maturing of the crop, some slight differences were noticeable. No. 3, the plot having dissolved bone black alone, was noticed to have a more uniform growth and a greater average height than any plots near it. No. 5, the plot having dissolved bone black and dried blood was noted as being better in appearance than any that preceded it. In No. 8 the absence of a fertilizer was very plainly marked. No. 11 had the advantage of a more healthy color than No. 12, but the growths seemed about equal. The addition of sulphate of ammonia to plots 18, 19, and 20, was noted as being apparently without effect. The differences above noted were apparently continued until the maturing of the corn. The slight differences in appearance during growth and in the final results I do not hesitate to attribute to the extremely dry weather of the corn season. There follows a summary of the temperature and rain-fall for the season.

TEMPERATURES AND RAIN-FALL.—We have been careful to record the temperatures of the weather regularly three times each day, viz., at 7 a. m., at 2 p. m., and 9 p. m. Having these temperatures, and also the amount of rain-fall, we have calculated the average temperature of each month, which we will give in connection with the amount of rain-fall:

Months.	Average temperature.	Total rain-fall.
	°*F.*	*Inches.*
May	66.3°	3.18
June	69.0°	5.87
July	77.5°	0.56
August	77.8°	0.70

From the above it will be readily seen that the first two months of the corn season—May and June—were favorable for a maximum crop, and up to the last of June the appearance of the corn crop was very promising. But during the two following months—July and August—the weather being very warm and extremely dry, the corn suffered very much, and the result was almost an entire failure.

TABLE D.—*Results of experiments with corn, Eastern Farm.*

	Number of plot.	Kind of fertilizer.	Quantities of fertilizers per acre.	Quantities of valuable ingredients applied per acre.			Yield of ears of corn per plot.	Yield of shelled corn per acre.
				Nitrogen.	Phosphoric acid.	Potash.		
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Pounds.*	*Bushels.*
	1	Nothing					67.5	18
A.—Valuable ingredients, singly.	2	Dried blood	240	24			68.5	18.3
	3	Dissolved bone	300		48		84.5	22.5
	4	Muriate of potash	200			100	58.8	15.7
B.—Valuable ingredients, two by two.	5	Dried blood	240					
		Dissolved bone	300	24	48		86	22.8
	6	Dried blood	240					
		Muriate of potash	200	24		100	82.3	22
	7	Dissolved bone	300					
		Muriate of potash	200		48	100	74	19.6
	8	Nothing					62.3	16.6
C.—Complete fertilizer,† nitrogen in varying proportions from dried blood.	9	Mineral fertilizers,*dried blood.	240	24	48	100	60	16
	10	Mineral fertilizers, dried blood.	480	48	48	100	77.3	20.6
	11	Mineral fertilizers, dried blood.	720	72	48	100	67.8	18
D.—Complete fertilizer, nitrogen in varying proportions from nitrate of soda.	12	Mineral fertilizers			48	100	67	17.8
	13	Mineral fertilizers, nitrate of soda.	160	24	48	100	65.5	17.4
	14	Mineral fertilizers, nitrate of soda.	320	48	48	100	76	20.4
	15	Mineral fertilizers, nitrate of soda.	480	72	48	100	79.3	21.1
	16	Nothing					69.3	18.5
E.—Complete fertilizer, nitrogen in varying proportions from sulphate of ammonia.	17	Mineral fertilizers			48	100	69.8	18.6
	18	Mineral fertilizers, sulphate of ammonia.	120	24	48	100	70	18.6
	19	Mineral fertilizers, sulphate of ammonia.	240	48	48	100	67.8	18
	20	Mineral fertilizers, sulphate of ammonia.	320	72	48	100	70.3	18.8
	21	Yard manure	12,000	52.4	25	60.4	70.5	18.8
	22	Plaster	320				65.3	17.4

* Same as plot 7.

† Containing all the valuable ingredients.

The following is a summary of the results as given in the previous tables:

TABLE E—*Summary of Table D.*

Kind of fertilizer.		Quantities of valuable ingredients applied per acre.			Yield of shelled corn per acre.	Increase of yield per acre over no fertilizer.
		Nitrogen.	Phosphoric acid.	Potash.		
		Pounds.	*Pounds.*	*Pounds.*	*Bushels.*	*Bushels.*
Average of 3 plots	Nothing				17.7	
One plot	Dried blood	24			18.3	0.6
One plot	Dissolved bone		48		22.5	4.8
One plot	Muriate of potash			100	15.7	—2.0
One plot	Dried blood; dissolved bone	24	48		22.8	5.1
One plot	Dried blood; muriate of potash	24		100	22	4.3
Average of 3 plots	Dissolved bone; muriate of potash		48	100	18.6	0.9
Average of 3 plots	Mineral fertilizers and smallest amount nitrogen.	24	48	100	17.3	—0.4
Average of 3 plots	Mineral fertilizers and medium amount nitrogen.	48	48	100	19.6	1.9
Average of 3 plots	Mineral fertilizers and largest amount nitrogen.	72	48	100	19.3	1.6
One plot	Yard manure	52.4	25	60.4	18.8	1.1
One plot	Plaster				17.4	0.3

Professor Jordan summarizes the results of his experiments as follows:

None of the fertilizers produced any material increase of crop, not even the farmer's old "stand-by," yard manure. So long as this is the case, we cannot discuss the relative effect of the different fertilizers, for none of them had any effect. All the good we can hope to gain then from the experiments is, to discover, if possible, whether anything in the method of cultivation or the application of the fertilizers was the cause of their not producing any effect. If the peculiar conditions of the season were responsible for the failure of the various manures to act, it is equally important to know what were the exact causes operating to induce such a result. Below is a summary of the temperatures and rain-fall at the two farms, the figures for the Central Farm being kindly furnished by Prof. C. Alfred Smith.

Months.	Central farm.		Eastern farm.	
	Average temperature.	Total rain-fall.	Average temperature.	Total rain-fall.
	° *F.*	*Inches.*	° *F.*	*Inches.*
May	67	2.82	66.3	3.18
June	68	6.82	69.0	5.87
July	79	2.83	77.5	0.56
August	76	0.86	77.8	0.70
September	78	0.60	.....	.....

It is to be noticed that the temperatures for July and August are very high, while the amount of rain-fall is very small.

The extreme dryness, caused by the great heat and the lack of rain-fall, is undoubtedly the direct cause of no increase crop resulting from the use of the fertilizers. As the commercial fertilizers were sown broadcast, and as the yard manure used was not fermented, we should not expect either kind of fertilizer to have much effect until after considerable root development had taken place, or until the more advanced stages of growth. When that time arrived the lack of soil water prevented a growth at all commensurate with the supply of food available to the plants. In other words, water was the missing ingredient of plant-food, so that no matter how much else might be present for use it could not be utilized. Such an explanation is, of course, of the most general nature. Only after the experiments of several years can one be offered more in detail.

In brief, Professor Jordan's experiments of 1881 were so affected by severe drouth that none of the fertilizing materials brought much increase. But the experiments are rationally planned, the questions studied are specific and not numerous, the work is being thoroughly done, accurate observations are made of the numerous conditions, including especially the weather, and the trials are to be continued through a series of years with crops succeeding one another in regular rotation.

We have here a rational, systematic, and thorough series of investigations, comparable with each other and with similar ones elsewhere. The outcome cannot fail to be of great value.

As regards the effects of nitrogen upon the growth of corn, the results of the one season's experiments, as far as they go, accord with those elsewhere obtained, in that the corn gives very little response to nitrogen. Indeed, in some of the trials, less of both corn and stalks

was obtained with the nitrogenous fertilizers than without them. The same result was noticed in several of the nitrogen experiments previously described. (Appendix, Tables I to III.)

The oats paid more heed to the nitrogen, though the increase was small, only four bushels per acre, with the smallest ration, 24 pounds per acre, and even less with the larger quantities of nitrogen.

EXPERIMENTS BY MR. SANBORN, OF THE NEW HAMPSHIRE AGRICULTURAL COLLEGE.

Mr. J. W. Sanborn, farm superintendent of the New Hampshire Agricultural College at Hanover, has been conducting, for some four years past, on the farm of that institution, several series of field experiments, in one of which the effects of phosphatic, potassic, and nitrogenous fertilizers have been studied in a method analogous to that of the Special Nitrogen Experiments above detailed.

The experiments were begun in 1878, and have been continued, with the same fertilizers and crops on the same plots, to the present. The plots were each four rods long and two rods wide, and separated by vacant spaces. The crops have been corn and potatoes. The plan may be seen in the following table from Mr. Sanborn's report for 1879, which includes so much of one of the experiments, that with corn, as has a direct bearing upon the question of the nitrogen supply.

The soil is described by Mr. Sanborn as "an alluvial, undrained, clayey soil," "not well adapted to potatoes," and one on which "corn does not follow corn successfully." Before the experiment it had been in grass, and was in condition to yield 1½ tons of hay per acre. The season of 1879 was "cold in the spring and backward and dry during the formation and early development of the ear." Some of the results obtained in 1878 are included in the table with those of 1879:

Experiment with corn, 1879, by Mr. J. W. Sanborn.

Plots.	Materials used.	Furnishing	Yield sound corn, bushels.	Yield soft corn, bushels.	Total yield, bushels.	Yield 1878.	Yield over nothing plot, 1879.	Yield over nothing plot, 1878.	Cost of fertilizer.	Value of corn.	Value of corn and stover.	Value of increase, corn and stover.	Stover, pounds.	Pounds stover to bushel corn.
28	186 pounds dissolved bone-black 128 pounds muriate potash 320 pounds sulphate ammonia	31 pounds phosphoric acid 67 pounds potash 64 pounds nitrogen	29.4	16.4	45.8	69	17	38	$21 33	$34 35	$45 28	$18 61	5,400	118
29	186 pounds dissolved bone black 128 pounds muriate potash 240 pounds sulphate ammonia	31 pounds phosphoric acid 67 pounds potash 48 pounds nitrogen	44.7	16.4	61.1	65	32.3	34	17 53	42 32	62 84	36 17	6,640	10.2
30	186 pounds dissolved bone black 128 pounds muriate potash 160 pounds sulphate ammonia	31 pounds phosphoric acid 67 pounds potash 32 pounds nitrogen	50.6	14	64.6	53.3	35.6	22.5	13 73	46 08	64 68	39 01	6,200	96
31	186 pounds dissolved bone-black 128 pounds muriate potash 80 pounds sulphate ammonia	31 pounds phosphoric acid 67 pounds potash 16 pounds nitrogen	55.5	13.5	69	48	40.2	17	9 93	49 80	68 70	42 03	6,300	91
32	186 pounds dissolved bone black 128 pounds muriate potash	31 pounds phosphoric acid 67 pounds potash	52.2	15.2	67.4	27	38.6	6	6 13	47 84	62 20	35 53	4,800	71
33	186 pounds dissolved bone black 64 pounds muriate potash 320 pounds sulphate ammonia	31 pounds phosphoric acid 33½ pounds potash 64 pounds nitrogen	38.8	14	52.8	.....	24	.....	19 99	36 64	48 04	21 37	3,800	74
34	Nothing		12.4	12.8	25.2	.....	.....	.....	.....	15 04	25 54	.....	3,500	138
35	160 pounds dissolved bone-black 320 pounds sulphate ammonia	31 pounds phosphoric acid 64 pounds nitrogen	No yield practically						18 45	.....	2 10	Loss. 2 57	700	.....
36	93 pounds dissolved bone-black 128 pounds muriate potash 320 pounds sulphate ammonia	15½ pounds phosphoric acid 67 pounds potash 64 pounds nitrogen	13.6	17.1	30.7	....	1.9	.....	19 71	17 72	25 52	Loss. 1 15	2,600	84
38	128 pounds muriate potash 320 pounds sulphate ammonia	67 pounds potash 64 pounds nitrogen	14.5	19.7	34.2	.....	5.4	24.5	16 06	25 28	38 18	11 51	4,300	122
39	186 pounds dissolved bone black	31 pounds phosphoric acid	15	18.1	33.1	55.5	4.3	4.5	3 25	19 24	29 44	2 77	3,400	102
40	Nothing		20.2	13.8	34	35	5.2	.....	.....	21 68	32 78	6 11	3,700	109
41	128 pounds muriate potash	67 pounds potash	47.3	16.6	63.9	59.5	35.1	28	2 88	44 48	56 48	29 61	4,000	62
42	320 pounds sulphate ammonia	64 pounds nitrogen	15	16.9	31.9	36.2	3.1	5.2	15 20	18 76	37 06	10 30	6,100	191
44	16 tons yard manure	Estimated to contain twice material, plot 28.	90.1	9	99.1	62.6	70.3	31.3	28 00	72 44	185 44	78 77	11,000	111
44½	Nothing		8.7	16.2	24.9	....	.....	.....	.....	13 44	20 88	.....	2,480	99
48	160 pounds magnesia 80 pounds salt 120 pounds lime	—phosphoric acid 33.6 pounds potash 74.2 pounds nitrogen	8.7	12.5	21.2	43.8	Loss. 7.6	....	.....	11 96	20 78	Loss. 5 89	2,940	134
49	1,000 pounds decorticated cotton-seed meal		35.3	14.1	49.4	.....	20.6	.....	16 00	33 88	54 58	27 91	6,900	139
51	Nothing		1.83	12.8	31.1	31	.....	.....	.....	19 76	27 56	.....	3,600	115
54	40 bushels ashes		4.99	9.9	56.8	38	22.0	7	10 00	36 68	55 28	29 61	6,200	121

Mr. Sanborn comments upon these results as follows:

One of the most striking and important results brought out by the table is the relation of the ammonia salts to the crop, and its contrast to results of last season. Last year an increasing quantity of ammonia salts gave an increasing crop up to the largest amount used in plot 28; and everywhere where used, on all plots, both to corn and potatoes, in connection with minerals, gave a large increase of crop for its use, and a profit for use up to three-fourths formula, or amount used in plot 29, notwithstanding its very high cost. This season wherever used it brings a loss, excepting a very slight gain for one-fourth part as in plot 31 over 32, but not a profitable gain. Plot 42 gives, it is true, a little more than the average of the nothing plots, but not so much as plot 40 near to it. And I may add here as a very interesting fact, apparently, that plots 40 and 31 represent probably the true native fertility of the soil for the season better than 34 or 44½; for 34 and 44½ were fallow for the season of 1878, while the others bore heavy crops for unmanured land. I have other facts that in a future paper I shall allude to, that go strongly to show that the bare fallow was, at least so far as this season's crop is concerned, an injury. If my conclusions are right, the experimental land is of rarely uniform fertility. The two bare fallowed last year agreeing nearly in crop, and the other two that bore a crop corresponding very close in yield. The plots run in rows of nine, parallel to each other, thus the nothing plots are well interspersed among the fertilized plots

But to return to the ammonia plots. I observed that the stalks were not so vigorous as those to minerals alone, or minerals and a slight quantity of ammonia salts, and were, as my record shows, an easy prey to worms. Why this result? Is it due to the quality of the ammonia? No; because the minerals alone gave as good crop as could have been expected had the ammonia salts been added with complete success as in plots 41 and 54 and 32. In 32 only potash salts were used to give theoretically 43 bushels of increase of crop of corn, yet without any ammonia 38.6 bushels of increase was made. Now the same plot gave but 6 bushels increase over nothing plot last year. So of ashes and other mineral plots; they gave but little or no increase both on corn and potatoes over nothing plots, while this year they give as good results as last year when ammonia salts were profitably used. Neither was it due to ammonia salts left over in the soil; for the mineral plots had no ammonia salts, and in case of those plots that did have a liberal use of them the increase of crop was so heavy as to absorb nearly all of these salts. Nor is it due to any carelessness of mine, or to a local influence; for I put out several experimental sets and in different sections of the State and on diverse soils, and the results come to me the same. I would call particular attention to this point, because no question in fertilization is at once so difficult and important to fathom. Last year, in round numbers, $12 worth of ammonia salts paid a profit for use. This year they are worse than useless, and are over one-half of the cost of fertilization for an acre of corn; yet had they not been used last season but little increase of crop (6 bushels) would have been harvested. I can only say that I believe that the character of the season has more to do with the ability of a plant to gather its nitrogen from natural sources than has been generally recognized, and that at present science does not explain it fully, nor can we at present combine fertilizers for seasons. We may, however, accept the averages of several seasons as the safest mean. It would appear to me to be prudent for the time to use about one-half of what has become to be known as full formula of nitrogen for corn. By comparatively recent experiments of Berthelot and others, it appears that the electrical condition of the atmosphere has much to do with the power of a plant to gather its nitrogen nourishment from the natural source, from the air, and that that condition is quite variable in different seasons and in the same season.

POTASH THE MANURE OF THE CROP.

It will be noticed, on comparison of plots, that the presence or absence of potash

affects the crop more than either of the other materials. This same result has been noticed here for the three years of my observation, both on the plot work and in the main field. The fertilizers ordinarily put upon the market containing no potash would thus be of little use on this farm, and this is the experience of my neighbors up and down the river on land of the character of this farm. I respectfully suggest that if they would use potash salts with superphosphates, more satisfactory results would probably be obtained.

These experiments have continued through four seasons, from 1878 to 1881. No detailed account of the whole has as yet been published. Mr. Sanborn has, however, kindly favored me with a brief summary of results of the four years in the following form:

I take it that you simply desire a statistical statement of crop returns from the nitrogen plots alone, and this I give you in brief tables.

Experiments on effects of nitrogenous and other fertilizers upon corn in 1878, 1879, 1880, *and* 1881.

By Mr. J. W. Sanborn, *New Hampshire Agricultural College.*

SHELLED CORN.

Number of plot.	Fertilizers per acre.		Yield per acre in bushels, stalks in pounds.															
			1878.				1879.				1880.				1881.			
	Materials.	Ingredients.	Sound.	Soft.	Total.	Stalks.	Sound.	Soft.	Total.	Stalks.	Sound.	Soft.	Total.	Stalks.	Sound.	Soft.	Total	Stalks.
28	320 pounds sulph. of ammonia... 186 pounds dis. bone black..... 128 pounds mur. of potash	64 pounds nitrogen... 36 pounds phos. acid. 77 pounds potash	66.5	2.5	69.0	5,480	29.4	16.4	45.8	5,400	7.8	1.5	9.4	2,060	16.5	5.8	22.5	4,000
*29	240 pounds sulph. of ammonia... 186 pounds dis. bone black ..... 128 poundsmur. of potash.....	48 pounds nitrogen... 31 pounds phos. acid. 77 pounds potash ...	60.0	5.0	65.0	5,320	44.7	16.4	61.1	6,640	16.1	4.1	20.2	2,940	25.5	5.7	31.3	4,967
30	160 pounds sulp. of ammonia... 186 pounds dis. bone black..... 128 pounds mur. of potash	32 pounds nitrogen... 31 pounds phos. acid. 77 pounds potash.....	48.5	5.0	53.5	4,200	50.6	14.0	64.6	6,200	15.6	6.5	22.1	2,940	29.8	5.8	35.5	4,300
31	80 pounds sulp. of ammonia ... 186 pounds dis. bone black..... 128 pounds mur. of potash.....	16 pounds nitrogen... 31 pounds phos. acid. 77 pounds potash ...	44.0	4.0	48.0	4,340	55.5	13.5	69.0	6,300	29.4	2.1	31.5	3,100	36.0	5.0	41.0	4,460
32	186 pounds dis. bone black ..... 128 pounds mur. of potash.....	31 pounds phos. acid. 77 pounds potash ...	33.8	3.2	37.0	2,640	52.5	15.2	67.7	4,800	28.2	3.8	32.0	2,740	†30.4	4.7	34.8	3,700
34	Nothing	.....	33.8	.....	.....	.....	12.4	12.8	25.2	3,500	0.0	3.2	.....	1,040	1.8	5.1	67.8	2,400
35	186 pounds dis. bone black..... 320 pounds sulp. of ammonia....	31 pounds phos. acid. 64 pounds nitrogen...	.....	.....	.....	.....	worthless.			.....	0.0	1.0	.....	380	0.0	1.8	.....	700
38	128 pounds mur. of potash..... 320 sulph. of ammonia.....	77 pounds potash..... 64 pounds nitrogen.....	53.8	1.8	55.5	4,160	1.5	11.5	26.5	3,400	5.2	1.9	7.1	1,700	22.0	8.2	28.2	2,900
40	Nothing	.....	.....	.....	40	.....	.....	.....	.....	.....	4.3	3.2	7.5	1,300	3.0	8.0	8.0	2,000
42	320 pounds sulph, of ammonia..	64 pounds nitrogen	57.8	1.8	58.5	2,420	20.2	13.8	34.0	3,700	1.7	1.5	3.2	600	0.0	2.5	2.5	800
54	30 to 40 bu. ashes	.....	.....	.....	38.0	4,460	40.9	9.9	50.8	6,200	31.1	2.3	33.4	2,840	47.2	3.8	81.0	4,000

* It was found after the experiments were started that in the distant past charcoal had been burned on plot 29. The fourth year 300 pounds dis. bone black was used The fourth year and third year 240 and 160 pounds of muriate of potash were used respectively.

† Plot 32 was injured by some cause. If the hills had been complete it would have been as good as 31.

Experiments on effects of nitrogenous and other fertilizers upon potatoes in 1878, 1879, 1880, *and* 1881.

By Mr. J. W. Sanborn, *New Hampshire Agricultural College.*

Number of plot.	Fertilizers per acre.		Yield per acre in bushels.											
			1878.			1879.			1880.			1881.		
			Marketable.	Small.	Total.	Marketable.	Small.	Total.	Marketable.	Small.	Total.	Marketable.	Small.	Total.
1	105 pounds sulphate of ammonia, mineral manures*	21 pounds nitrogen. 11 to 15 pounds phosphoric acid. 34 to 60 pounds potash.	122.5	83.5	206.0	96.0	48.0	144.0	85.3	63.9	149.2	15.3	32.0	47.3
2	Nothing		39.0	83.6	122.6	6.0	50.3	56.3	7.5	58.6	66.1	.....	15.6	15.6
3	52½ pounds sulphate of ammonia, mineral manures*	10.5 pounds nitrogen minerals*	115.6	76.6	192.2	95.0	46.6	171.6	62.6	69.5	132.1	20.3	22.3	42.6
4	Mineral manures		101.0	73.6	174.6	107.6	49.0	156.6	76.6	71.3	147.9	22.5	22.0	44.5
6	105 pounds sulphate of ammonia, potash salt	21 pounds nitrogen potash*	129.0	69.3	198.3	70.3	57.3	127.6	80.3	74.3	154.6	19.0	30.3	49.3
10	105 pounds sulphate of ammonia, superphosphate*	21 pounds nitrogen phosphoric acid.	62.5	58.4	120.9	23.6	37.6	61.3	24.5	61.6	86.1	7.3	21.5	28.8
12	105 pounds sulphate of ammonia	21 pounds nitrogen	80.3	80.4	164.3	47.0	47.0	94.0	40.7	55.3	96.0	8.3	20.8	29.1

* Superphosphate and potash salt as in corn experiment. (See preceding table).

The results of the use of ammonia for corn are a source of inexplicable astonishment to me. Various reasons have suggested themselves to me, but each fail to account for the results. It is known that sulphate of ammonia is sometimes in its production accompanied with injurious matter or matters. I doubt if this accounts for the results, as I do not note it in the potatoes. It is noteworthy that the ashes are steadily increasing the crop, although they contain no nitrogen, and last season was unfavorable.

I may say that on the plots with large rations of nitrogen, the corn starts well, looks healthy for awhile, but gradually it turns to a sickly color, and in many cases dies out completely. On the plot with nitrogen alone in 1881, nearly all of the corn was alive in August, but gradually disappeared, so that before harvest it was mostly gone.

The coming season I propose to investigate this matter of the injurious effect of nitrogen.

Regarding the results with the potatoes I have no comments to make other than that the unreported plots that received no nitrogen, when compared with those that have nitrogen, puzzled me for awhile. I now find it clear that the sulphuric acid in the bone black and sulphate of ammonia have affected the results favorably, and that whatever gain comes from the use of either superphosphate or sulphate of ammonia is due wholly to the sulphuric acid they contain.

Mr. Sanborn's experiments seem to me among the most interesting I have seen. That the soil should have proven so uniform, as shown by the agreement of the results on the unmanured plots, even when the plots were in checks rather than in long, narrow strips, is most fortunate.

That sulphate of ammonia should so materially benefit the corn the first season, injure it the second, and, in succeding years, almost destroy it, is certainly very strange. The increase of the yield year after year with ashes is likewise remarkable. All these phenomena demand careful and thorough investigation.

It is perhaps worthy of note in this connection that the experiment of Colonel Mead, of Vermont (see Appendix, Table I), in which nitrogen proved injurious rather than helpful to the corn while potash was so beneficial, was not very far from Hanover, N. H., where Mr. Sanborn's experiments were made.

Mr. Sanborn informs me that he has made arrangements to bring his experiments as nearly as possible into accord with the co-operative plan followed by the experimenter whose work has been set forth in Tables I–III, appendix.

In the language above quoted and elsewhere, Mr. Sanborn strongly urges the importance of the study of the demands of soil and crop by experiment. In connection (I believe) with the New Hampshire board of agriculture, the agricultural college, through Mr. Sanborn, has induced farmers in various parts of the State to institute trials with fertilizers containing nitrogen, phosphoric acid, potash, &c., similar to the "general experiments," described in the earlier part of this article. The results, so far as published, amply justify Mr. Sanborn's recommendations and conclusions.

EXPERIMENTS AT THE UNIVERSITY OF TENNESSEE BY PROFESSOR M'BRYDE.

Prof. J. M. McBryde, of the University of Tennessee, at Knoxville, has lately reported a series of experiments analagous to those described above and with similar purpose, though the questions studied are much more numerous.*

In view of the publicity already given to these experiments, and the lack of space here, I refrain from quoting the details.

The results of Professor McBryde's experiments, however, accord with the general impression which makes nitrogen the most efficient of the fertilizing elements in promoting the growth of wheat. From the strictly practical stand-point also, they are of interest in illustrating how the use of concentrated fertilizers often brings more of loss than gain. Unfortunately the differences in produce of the different plots is, as Professor McBryde urges, hardly great enough to exceed the limits of error due to inequalities of soil, and with so few duplicate tests the results will hardly warrant generalizations even for the conditions in which the trials were made.

Such extensive and painstaking investigations are, nevertheless, of great value, and will become increasingly so as they are continued from year to year.

GENERAL DISCUSSION OF RESULTS OF THE EXPERIMENTS.

THE FEEDING CAPACITIES OF PLANTS.

The experiments we are discussing bring us face to face with one of the most important problems with which agricultural chemistry has to deal, and, at the same time, throw some new light upon it. I refer to what may perhaps be called their feeding capacities, their power of gathering their supplies of food from soil and air, and the effects of the different ingredients of plant food upon their growth.

A vast deal of experience in the laboratory and in the field bear testimony to the fact, though we are still deplorably in the dark, as to how or why it is so, that different plants have different capacities for making use of the stores of food that soil and air contain. Thus experience and experiments tell us that clover and, perhaps, leguminous plants generally do somehow or other succeed in obtaining a sufficient supply of nitrogen, where cereals, such as wheat, barley, rye, and oats would half starve for want of it, and this in the face of the fact that leguminous plants contain a great deal of nitrogen and the cereals relatively little. Hence a heavy nitrogenous manuring may be profitable for wheat and be in large part lost on clover.

* Experimental work of the Agricultural Department of the University of Tennesse 1881. A portion of the same report, also given in an article by the same author, entitled "Chemical Manures on Wheat," in the Agricultural Review, January, 1882, page 75.

As long ago as 1850, Dr. Pusey said in a report "On the progress of agricultural knowledge during the last eight years," in the Journal of the Royal Agricultural Society (vol. xi. 1850, pp. 385–6), "At present we can only say that the three leading principles of manure are: 1, Ammonia; 2, Phosphorus; and, probably 3, Carbon;" and again, "The upshot of the whole is that practically, as far as artificial manures are concerned, we need not dwell upon the mineral ingredients, but must give ammonia to wheat, and to turnips phosphorus." Since Dr. Pusey's time we have got hold of very many new facts, theories of manuring have multiplied, and fertilizers for special crops, based upon various theories, have come into very general use.

The little definite knowledge we have of the different feeding capacities of plants comes in part from general observation and in part from direct experiment.

The experimental data have been contributed by various investigators, especially by Messrs. Lawes and Gilbert, of England, whose classic researches on the fields and in the laboratory at Rothamsted are familiar to all students of agricultural science.

Next in prominence, perhaps, in this field of discussion is M. Georges Ville, of France, whose experiments, however, do not compare in extent with those of Messrs. Lawes and Gilbert, but whose theories are much more numerous and definite.

How it is, by virtue of what characteristics, organs, or functions of different plants they possess these different capacities for gathering their food are questions still to be solved. Sir John Lawes, in an article on fertility, with which many of the readers of this are familiar, in discussing the relations of different plants to the nitrogen supply, says:

It is not to the difference of their capacity for taking nitrogen from the atmosphere that we must look for an explanation of the distinctive influence, or function, so to speak, of the crops grown in a rotation. The explanation is rather to be found in the difference in the character and length of life of the different plants, in the character of the roots in regard to number, range, size, and to their aptitude to derive more of their food and moisture from the surface, or from the subsoil, and finally, in the greater capacity of some for liberating and assimilating food not available to others, or for arresting food which would otherwise be washed out of the soil. * * * *

If we consider the well-established characteristics of the various leguminous crops grown in rotation, and the circumstances of their growth, it will be seen that their powers of taking up nitrogen and of contributing to the increased growth of succeeding crops are much in proportion to the length of their lives and the range of their roots. Thus every one will admit that lucern, sainfoin, and red clover will grow larger crops without manure, and will leave a larger residue for the growth of succeeding crops, than either white clover or tares.

Again, if we follow the course of a barley and of a red-clover crop, both sown nearly at the same time, it will be seen that when the barley has ripened its seed the active growth of the clover has scarcely commenced, and the plant has still the latter part of the summer, the whole of the autumn, and to the autumn of the succeeding year to collect its food. A man would consider himself very unfairly handicapped if he were required to do as much work in four months as another was allowed eighteen months in which to perform it. After the cessation of the life of the barley, the formation of

nitric acid in the soil is doubtless still active. In fact direct experiments show that the autumn drainage removes more nitrates than that of other periods of the year.

It is doubtless one of the economic functions of the clover plant to arrest and store up the nitrogen of the nitric acid in the soil which would otherwise be drained away during the autumn and winter. Whether or not the leguminosæ may further take up any of their nitrogen directly from the nitrogenous organic matter within the soil there is no direct evidence to show, though there are some facts which might be held to lend probability to the assumption.

When we see that the appearance of a fungus, even on very poor grass land, is always accompanied by a rich growth of grass, we conclude that it has the property of liberating and utilizing nitrogenous compounds in the soil which the grasses were unable of themselves to turn to account. It is, at any rate, not impossible that the leguminosæ may likewise derive at least a portion of their nitrogen from the nitrogenous organic compounds within the soil; but their possession of green leaves may be taken as evidence that they derive the chief of their carbon from other sources than the organic carbon of the soil.

The above remarks are made by their author in a discussion of the question whether plants obtain any considerable quantity of their nitrogen from the air—a question which he is inclined to answer quite decidedly in the negative. They seem to me, however, to apply very aptly to the more general problem of the capacities of plants.

If the superior faculty of clover, as compared with wheat, for accumulating nitrogen be due to its larger amount of root surface, and its longer period in which this gathering is done, why may it not for the same reasons be better able than wheat to obtain its phosphoric acid, potash, and other food ingredients? Indeed, why may not any characteristic which gives clover an especial ability to gather its nitrogen be equally efficient as regards the lime, or phosphoric acid, or potash? The point seems to me to lie here: Plants differ in these respects. Why they differ, we may surmise, but cannot affirm. What we need to do is to find out; and the experimental data needed are to be sought partly in the greenhouse and partly in the field.

THE VILLE THEORIES OF FERTILIZATION.

Of the various theories of fertilization perhaps no others have attracted so much attention as those of Professor Ville, whose experiments on the government farm at Vincennes during more than a quarter of a century have been discussed, and whose writings are read the world over. The prominence which the doctrines of Ville have obtained in the agricultural press, and among farmers in this country, coupled with the marked discrepancy between them and the results of the large number of experiments here detailed, seems to warrant at least a brief discussion of the theory.

One of the essential features of Ville's doctrine is the theory of dominant ingredients. He gives "the name *dominant* to the ingredient which, for a given crop, plays a more important part than the others." Thus:

Nitrogen is the predominant ingredient for the cereals, as wheat, barley, rye, oats, and for colza, sugar-beet, hemp, &c.

Potash has an especial influence upon peas, beans, clover, lucern, flax, potatoes, &c.

Phosphoric acid is especially beneficial for turnips, rutabagas, radishes, Indian corn, sugar cane, &c.

Lime seems to exert no especial preponderating action upon any plant, but is necessary for all.

Of the numerous ingredients of fertilizers Ville regards the four named, nitrogen, phosphate of lime (phosphoric acid), potash, and lime, as the regulators *par excellence* of production, and the only ones with which agricultural industry need occupy itself. His formulas for "complete manures" supply these four ingredients—the *nitrogen* as nitrate of potash (saltpeter), nitrate of soda, or sulphate of ammonia; the *phosphoric acid* in the form of superphosphate; the *potash*, in either nitrate of potash, or other potash salts, and the *lime* as sulphate of lime (land plaster). He says that "the mixture of these substances has the same properties as dung." The "complete chemical manure is to the barn-yard manure what the metal is to the ore." "It is farm-yard manure divested of all useless matter."

The practical inference is that in preparing a fertilizer for a given plant, we must reduce the subordinate ingredients as much as we can, and put in a good deal of the dominant. To sustain his propositions, Ville cites a great many experiments, some made by himself in pots or in the fields of the experimental farm at Vincennes, and others by farmers in France and elsewhere. In an experiment on wheat, for instance, one plot received a "complete manure;" from another the lime (sulphate of lime) was omitted, while the third had no potash, &c.

Fertilizer.	Yield of wheat per acre.
	Bushels.
Nothing	15.88
"Complete manure"	56.44
"Complete manure," without lime	53.38
"Complete manure," without potash	40.44
"Complete manure" without phosphoric acid	34.66
"Complete manure," without nitrogen	18.18

The wheat suffered more from lack of nitrogen than from lack of any other ingredient. Again, with sugar-beets, starting with a complete fertilizer which supplied 360 pounds of superphosphate, 180 pounds of nitrate of potash, 270 pounds of nitrate of soda, and 360 pounds of sulphate of lime per acre, when more lime, potash, or phosphoric acid was added, the yield was not affected, but when the nitrogen was increased the yield rose with it. From such experiments as these, Ville infers that nitrogen is the dominant ingredient for wheat and the sugar-beet, and consequently he puts a large proportion of it in his formulas for these crops. He insists, furthermore, that the form of combination is important, and uses sulphate of ammonia for wheat, nitrate of soda for

sugar-beets, and so on. For clover, beans, peas, &c., he recommends little or no nitrogen, because the plants are found to get very little if any good from nitrogenous manures. He explains this by assuming that such plants get all their nitrogen from the air, and do not need it in fertilizers. Of the theory once held by many that plants assimilate the free nitrogen of the air, Ville has been for some years almost the only prominent defender. He claims that clover gathers all its nitrogen from the air; that barley and rye get 80 per cent., wheat 50 per cent., and sugar-beet, 60 per cent. from the air, and the rest from the soil.

Concerning the mineral ingredients, phosphoric acid, potash, and lime, Ville's rule is to restore all that the crops remove, and a little more to make up for what is leached away by water in the soil below, beyond the reach of the roots of plants; thus strangely ignoring the resupply which every soil keeps up from the decomposition of its material.

COMPLETE OR NORMAL MANURES.

The formulas for chemical manures are one of the chief features of Ville's system. He sums up his doctrine of chemical manures as follows:

No. 1. The complete chemical manure embraces all the fertilizing principles of dung, all of whose active portion it contains, and to which it is superior in the harvests it brings.

No. 2. For the action of each one of the four substances of which the complete manure is composed (viz., phosphoric acid, potash, lime, and nitrogenous material), the co-operation of the three others is necessary.

No. 3. Each one of the four terms of the complete manure has a function subordinate or preponderant with respect to the other three, according to the nature of the plants. [The principle of dominants as above explained.]

No. 4. Analysis of the soil by culture.

That is, the testing of soils by experiments with different fertilizing materials, in order to find whether any are supplied in sufficient quantity by the soils, and may consequently be omitted from the fertilizers. Ville lays great stress upon these experiments and gives very full directions for conducting them.

CHEMICAL FERTILIZERS SUPERIOR TO FARM MANURES.

Ville claims that chemical fertilizers are superior to farm manures for several reasons:

(1.) They bring larger crops. In proof of this he cites several hundred experiments made by agricultural schools, societies, and private individuals, on wheat, oats, rye, barley, maize, potatoes, sugar-beets, sugar-cane, &c., in France, Belgium, Germany, Italy, and other countries. In fifty-one experiments with wheat, in which chemical and farm manures were compared, the chemicals brought larger crops in forty-seven, less in three, and the same in one case. In ninety-two experiments with sugar-beets the artificial fertilizers brought the best results in sixty-seven cases, the dung in twenty cases, and both the same in five cases. In thirty-two experiments with potatoes, the chemical manures brought more than horse-manure in twenty-five, less in six, and the same in one.

(2.) The chemical fertilizers are cheaper. To substantiate this he makes extended comparisons between the cost in France of farm manure and the corresponding chemical materials, and calculates that the manure is the dearer by some 6 per cent.

(3.) Chemicals are always at command, and in just such kinds and quantities as are needed, the only limit being the amount of capital to be invested.

(4.) The ingredients of chemical manures are ready for use at once, while in yard-manure they are slowly available.

(5.) Chemical manures are more easily and cheaply transported, handled, and applied.

(6.) Chemical manures can be divided so as to use for each crop its predominant regulating ingredient, and in each case only what is needed. Thus, in a rotation, nitrogen can be used for wheat or oats, phosphates for corn or turnips, and potash for clover. Or, if the soil supplies enough of any one ingredient for any crop, it can be omitted from the fertilizer and its cost saved.

CONTINUOUS USE OF CHEMICAL MANURES.

To the question whether chemical manures alone can be depended on and used with profit year after year, Ville replies:

Yes, under two conditions: 1st. Give the land in fertilizers more phosphate of lime, more lime, and more potash than the crop takes from it. 2d. Give it about 50 per cent. of the nitrogen of the harvest.

Ville says, very aptly:

The employment of chemical manures requires especial care. Like fine weapons, they show a full measure of their power only in hands that understand how to use them.

VILLE'S FORMULAS.

The following are some of Ville's principal formulas. The amounts are calculated per acre. In changing French weights into ours fractions are avoided. The costs are estimated at rates current in our large markets:

WHEAT.

Complete manure No. 1. [*Dominant, nitrogen.*]

Fertilizers.	Quantity.	Ingredients.	Quantity.	Cost.
	Pounds.		*Pounds.*	
Acid phosphate of lime	360	Phosphoric acid	54	$6 20
Nitrate of potash	180	Potash	79	16 20
		Nitrogen	23	
Sulphate of ammonia	225	Nitrogen	28	1 26
Total	*1,080			*33 86

* The author has made an omission in this table, as will be seen from the additions.

BARLEY, RYE, OATS, AND GRASS.

Complete manure No. 1. [*Dominant, nitrogen.*]

Only one-half of above amounts.

BEETS, CARROTS, GARDEN VEGETABLES, ETC.

Complete manure No. 2. [*Dominant, nitrogen.*]

Fertilizers.	Quantity.	Ingredients.	Quantity.	Cost.
	Pounds.		*Pounds.*	
Acid phosphate of lime	360	Phosphoric acid	54	$6 30
Nitrate of potash	180	Potash	79	16 20
		Nitrogen	23	
Nitrate of soda	270	Nitrogen	42	10 80
Sulphate of lime	270			1 08
Total	1,080			34 38

POTATOES.

Complete manure No. 3. [*Dominant, nitrogen.*]

Fertilizers.	Quantity.	Ingredients.	Quantity.	Cost.
	Pounds.		*Pounds.*	
Acid phosphate of lime	360	Phosphoric acid	54	$6 30
Nitrate of potash	270	Potash	119	24 30
		Nitrogen	35	
Sulphate of lime	270			1 08
Total	900			31 68

For worn-out soils complete manure No. 2 is preferable.

TURNIPS, RUTABAGAS, SORGHUM, SUGAR CANE, CORN (MAIZE).

Complete manure No. 5. [*Dominant, phosphoric acid.*]

Fertilizers.	Quantity.	Ingredients.	Quantity.	Cost.
	Pounds.		*Pounds.*	
Acid phosphate of lime	540	Phosphoric acid	81	$9 45
Nitrate of potash	180	Potash	79	16 20
		Nitrogen	24	
Sulphate of lime	360			1 44
Total	1,080			27 09

BEANS, PEASE, CLOVER, ETC.

Incomplete manure No. 2. [*Dominant, potash.*]

Fertilizers.	Quantity.	Ingredients.	Quantity.	Cost.
	Pounds.		*Pounds.*	
Acid phosphate of lime	360	Phosphoric acid	54	$6 30
Nitrate of potash	180	Potash	79	16 20
		Nitrogen	24	
Sulphate of lime	360			1 44
Total	900			23 94

This is "incomplete," in that part of the nitrogen (of No. 2) is omitted. As Ville assumes that the above plants get all their nitrogen from the air, he explains that the nitrate of potash is put in here for the sake of the potash, and that the small amount of nitrogen can do no harm.

THE EXPERIMENTS OF MESSRS. LAWES AND GILBERT.

By far the most valuable contribution to our knowledge of these subjects comes from the field experiments of Messrs. Lawes and Gilbert.

In their experiments, wheat, which has for thirty years received mineral manures alone, has averaged 16¾ bushels per acre yearly, against 14 bushels unmanured. The addition of sulphate of ammonia, with the same repeated cropping of the same land, brought the average up to 36 bushels per acre. The leguminous crops have told just the opposite story. Though they contain a good deal more nitrogen than wheat, they respond but slightly to nitrogen, and are greatly aided by mineral manures. In an experiment on the mixed herbage of grass-land, continued through twenty years, mineral manures without potash brought up the total crop 47 per cent., and the nitrogen in the crop 38 pounds per acre annually above the unmanured. And when potash was added to the mineral manures the crop was 67 per cent. larger, and contained 56 pounds more nitrogen per acre than the unmanured, the increase in nitrogen being in large measure due to the leguminous plants, which came in under the influence of the potash and replaced plants of other families.

In one case Messrs. Lawes and Gilbert found that a soil from which a clover crop had just been removed contained more nitrogen than it did before the clover was put in; that, in other words, the soil to a depth of 9 inches at least was positively enriched by the growth and removal of a highly nitrogenous (clover) crop.

Such facts help to explain why it is such good farm-practice to use mineral fertilizers, as plaster, bone, ashes, and potash salts, for mixed grasses and clover, and nitrogenous materials, like guano, sulphate of ammonia, and nitrate of soda, for grain crops. They help us to understand why clover is such an excellent preparatory crop for wheat, and so economical generally for plowing under to bring up poor soils. It gathers and stores plant-food, particularly nitrogen, and thus is itself a fertilizer.

In Messrs. Lawes and Gilbert's experiments the cereals have been most helped by nitrogen, next by phosphates, and very little by potash. The legumes have responded to mineral manures, especially potash, and paid little heed to nitrogen except where on meadow land they have, under the influence of nitrogenous manuring, gradually run out and the grasses have taken their place, just as they have replaced the grasses when mineral manures alone were used. Turnips have done best with superphosphates; and potatoes, I think, have seemed to demand potash, along with nitrogen and phosphates, for their best development.

For some time past the relation of the corn-plant to the nitrogen supply has been a much-vexed question. The main question is whether, like other cereals (wheat, barley, oats, grasses, &c.), corn has but little power to gather nitrogen from natural sources and requires nitroge-

Experiments on effects of nitrogenous and other fertilizers upon potatoes in 1878, 1879, 1880, and 1881.

By Mr. J. W. Sanborn, *New Hampshire Agricultural College.*

Number of plot.	Fertilizers per acre.		Yield per acre in bushels.											
			1878.			1879.			1880.			1881.		
			Marketable.	Small.	Total.	Marketable.	Small.	Total.	Marketable.	Small.	Total.	Marketable.	Small.	Total.
1	105 pounds sulphate of ammonia, mineral manures*	21 pounds nitrogen. 11 to 15 pounds phosphoric acid. 34 to 60 pounds potash.	122.5	83.5	206.0	96.0	48.0	144.0	85.3	63.9	149.2	15.3	32.0	47.3
2	Nothing		39.0	83.6	122.6	6.0	50.3	56.3	7.5	58.6	66.1	.....	15.6	15.6
3	52½ pounds sulphate of ammonia, mineral manures*	10.5 pounds nitrogen minerals*	115.6	76.6	192.2	95.0	46.6	171.6	62.6	69.5	132.1	20.3	22.3	42.6
4	Mineral manures		101.0	73.6	174.6	107.6	49.0	156.6	76.6	71.3	147.9	22.5	22.0	44.5
6	105 pounds sulphate of ammonia, potash salt	21 pounds nitrogen potash*	129.0	69.3	198.3	70.3	57.3	127.6	80.3	74.3	154.6	19.0	30.3	49.3
10	105 pounds sulphate of ammonia, superphosphate*	21 pounds nitrogen phosphoric acid.	62.5	58.4	120.9	23.6	37.6	61.3	24.5	61.6	86.1	7.3	21.5	28.8
12	105 pounds sulphate of ammonia	21 pounds nitrogen	80.3	80.4	164.3	47.0	47.0	94.0	40.7	55.3	96.0	8.3	20.8	29.1

* Superphosphate and potash salt as in corn experiment. (See preceding table).

greater capacity for taking up food from the soil than the wheat, but maize has other distinctive properties which require to be noticed. Compared with wheat, the active life of maize extends far longer into summer and autumn. In the south of France, maize sown in the beginning of May is ripe at the end of October; in the same locality wheat is ripe in July. The most active growth of maize takes place after the wheat has ceased to collect its food. During the summer and autumn nitric acid is largely formed in the soil, and is taken up by both wheat and maize; but the early ripening of the wheat stops further collection by that plant, while maize continues to collect until late in the autumn. The formation of nitric acid goes on in the soil after the wheat is removed, but much of this is washed out of the soil by the winter rains. We see, therefore, that maize, by its habits of growth, has access to more nitrogen, in the form of nitric acid, than wheat.

And we have, also, in this fact an explanation of the action of mineral manures. Superphosphate is said, by you, to be a better manure for maize than for wheat; both require phosphates and nitrogen, but the maize gets more nitrogen, and, consequently can take up more phosphate. In all soils exhausted by corn crops, you may predict with certainty that ammonia or nitric acid applied as manure will increase a wheat crop, there being a large balance of mineral food which cannot be taken up by the wheat in the absence of nitrogen.

One other point may be noticed. Maize contains a smaller amount of nitrogen than wheat; I have seen analyses which only showed one-half as much; probably one-fourth less would be nearer the average. Taking all these matters into consideration, if wheat and maize were grown continuously for experiment, I should expect that maize, if manured with manure such as wood ashes and superphosphate, would give a larger produce than wheat. But to produce full crops, both would require, in addition, large quantities of nitrogen to be supplied as ammonia or nitric acid.

In brief, Mr. Lawes would expect that corn, during its longer period of growth, would, with the aid of mineral fertilizers, produce a larger yield, and, of course, gather more nitrogen than a wheat crop; but he is at the same time inclined to class it with the cereals.

SPECIFIC EFFECTS OF THE DIFFERENT FERTILIZING MATERIALS.

As a means of studying the effects of the nitrogen, phosphoric acid, potash, and so on, we have prepared some tables, which we have got in the way of calling "tables of difference": Tables X and XI of the Appendix. These show very clearly the effect of each material—nitrate of soda, superphosphate, and muriate of potash—both when used alone and when mixed with the others; and also presents in a very clear light the uniformity or irregularity of the action of each one on the different plots of each experiment. For instance, the effect of nitrate of soda alone is found by subtracting the average yield with no manure from that of the nitrate of soda plot. To find its effect with superphosphate, the yield of the phosphoric acid plot is subtracted from that which had the mixture of the two. The increase with the complete fertilizer over that with the superphosphate and potash salt, gives the effect of the nitrate of soda again, and so on. Of course it is understood that these differences in a given case do not express exactly the effect of the nitrogen, phosphoric acid, or potash, nor even that of the fertilizer containing them. The indirect action of the fertilizer counts for something, and the irregularities in the different plots often a good deal more.

It would be wrong to assume, in the case of superphosphate for instance, that its effect was due exclusively to its phosphoric acid, since it contains also sulphuric acid and lime, which at times may be very effective.

It is to be noted, also, that the quantities of nitrogen, phosphoric acid, and potash are not the same, so that the figures should be understood as applying to the quantities actually used.

It will be noted that Table X contains, also, a column showing the effects of sulphuric acid and lime together in plaster. Bearing this consideration in mind, it will, for our present purpose, suffice to treat the effects of the several fertilizers as if they were due to their characteristic ingredients. How we may make use of these figures in studying the effects of the several ingredients may be illustrated by the experiments with corn, as set forth in part one of Table X.

EFFECTS UPON CORN.

1. *Effect upon phosphoric acid, i. e., of superphosphate.*—In eight experiments, Nos. B, 3, 6, 7, 8, 14, B1, and B2, phosphoric acid was decidedly the regulating ingredient, the crop responding uniformly to it, and paying comparatively little attention to the others. In thirteen experiments, Nos. A, C, 5, 11, 12, 15, 16, 18, 20, 21, 22, 23, and 24, the phosphoric acid, though not holding relatively so important a place, was more or less useful. In six experiments, Nos. 2, 4, 10, 13, 17, and 19, the phosphoric acid produced little or no effect, the average increase of the several plots of each experiment being less than 4 bushels per acre.

2. *Effect of potash, i. e., of muriate of potash.*—In three experiments, Nos. D, 4, and 20, potash was decidedly the regulating ingredient, the crops responding uniformly to it, and paying comparatively little attention to the others. In fifteen experiments, Nos. A, B, 6, 9, 11, 12, 13, 14, 17, 18, 19, 21, 22, 23, and 24, potash, though not holding so important a place, was more or less useful. In ten experiments, Nos. 2, 3, 5, 7, 8, 10, 15, 16, A1, and A2, potash produced little or no effect, the average increase of the several plots of each experiment being less than 4 bushels per acre.

3. *Effect of nitrogen, i. e., of nitrate of soda.*—In no experiment was nitrogen the regulating ingredient. In sixteen experiments, Nos. A, B, 2, 4, 6, 9, 11, 12, 13, 14, 15, 17, 20, 22, 23, and 24, nitrogen, though not holding a very important place, was more or less useful. In ten experiments, Nos. 3, 5, 7, 8, 10, 16, 18, 19, and 21, nitrogen produced little or no effect, the average increase of the several plots of each experiment being less than 4 bushels per acre.

Going over the experiments with corn in 1878–'79–'80–'81, as set forth in Table X, we may group the results with reference to the facts of the individual ingredients as follows:

1. *Phosphoric acid.*—This may be taken as the regulating ingredient in the following experiments:

1878. Nos. B, 3, 6, 7, 8, 14, B1, and B2. 1879. Nos. C, 3, 7, 11, 14, 17, 18, and 26. 1880. Nos. 1, G, 4, 8, 9, C, 13, 14, 15, and 20. 1881. Nos. C, N, and Q.

As more or less efficient in—

1878. Nos. A, D, 5, 11, 12, 15, 16, 18, 20, 21, 22, 23, and 24. 1879. Nos. 4, 5, 6, 8, 9, F, 13, 15, 20, 21, 22, 23, and 25. 1880. Nos. K, 11, 12, I, 18, and 19. 1881. No. O.

As inefficient in—

1878. Nos. 2, 4, 10, 13, 17, and 19. 1879. Nos. 1, 12, 16, 19, and E, 1880. Nos. 3, 5, 7, and H. 1881. Nos. P, M, and L.

2. *Potash* may be regarded as the regulating ingredient in the following experiments:

1878. Nos. D, 4, and 20. 1879. Nos. 6, F, 15, 22, and E. 1880. Nos. 3, 5, 16, and H. 1881. Nos. O, P.

As more or less efficient in—

1878. Nos. A, B, 6, 9, 11, 12, 13, 14, 17, 18, 19, 21, 22, 23, and 24. 1879. Nos. 7, 9, 12, 14, 21, and 23. 1880. Nos. K, 9, 11, 15, 18, and 20. 1881. No. C.

As inefficient in—

1878. Nos. 2, 3, 5, 7, 8, 10, 15, 16, A1, and A2. 1879. Nos. 1, C, 3, 4, 5, 8, 11, 13, 16, 17, 18, 19, 20, 25, and 26. 1880. Nos. 1, G, 4, 7, 8, C, 12, I, 14, 19. 1881. Nos. Q, N, L, M.

3. *Nitrogen* may be taken as the regulating ingredient in the following experiments:

1878. None. 1879. No. 4. 1880. No. K. 1881. No. L.

As more or less efficient in—

1878. Nos. A, B, 2, 4, 6, 9, 11, 12, 13, 14, 15, 17, 20, 22, 23, and 24. 1879. Nos. 5, 6, 9, 11, 12, 13, 14, 21, 22, 25, and 26. 1880. Nos. 1, G, I, and 19. 1881. Nos. Q, P.

As inefficient in—

1878. Nos. 3, 5, 7, 8, 10, 16, 18, 19, and 21. 1879. Nos. 1, C, 3, 7, 8, F, 15, 16, 17, 18, 19, 20, 23, and E. 1880. Nos. 3, 4, 5, 7, 8, 9, C, 11, 12, 14, 15, 16, H, 18, 20. 1881. Nos. O, N, M, C.

The above data for the effects of the nitrogen, phosphoric acid, and potash upon corn may be tabulated together as follows:

Effects of the fertilizing materials upon corn.	Superphosphate.				Muriate of potash.				Nitrate of soda.			
	Regulating ingredient.	More or less efficient.	Inefficient.	Total.	Regulating ingredient.	More or less efficient.	Inefficient.	Total.	Regulating ingredient.	More or less efficient.	Inefficient.	Total.
In twenty-seven experiments of 1878.	8	13	6	27	4	13	10	27	.....	16	11	27
In twenty-six experiments of 1879 ...	8	13	5	26	5	6	15	26	2	10	14	26
In twenty experiments of 1880.....	10	6	4	20	1	4	15	20	1	2	17	20
In seven experiments of 1881.....	3	2	2	7	2	1	4	7	1	2	4	7
In eighty experiments of 1878–'79–'80–'81	29	34	17	80	12	24	44	80	4	30	46	80

EFFECTS UPON POTATOES.

1. *Phosphoric acid.*—This may be taken as the regulating ingredient in the following experiments:

1878. Nos. 27, 32, 33. 1879. Nos. 27, C, 29, 30, 35, 37. 1880. Nos. 21, 22, 26. 1881. C, I.

As more or less efficient in—

1878. Nos. 26, 28, 29, 30, 31. 1879. Nos. 31, 34. 1880. No. C. 1881. No. M.

As efficient in—

1878. No. 25. 1879. Nos. 33, 36. 1880. Nos. 23, 25. 1881. None.

2. *Potash.*—This may be taken as the regulating ingredient in the following experiments:

1878. Nos. 26, 28, 29, 30, 31. 1879. Nos. 27, 31, 34. 1880. No. C. 1881. None.

As more or less efficient in—

1878. Nos. 27, 32, 33. 1879. Nos. 29, 30. 1880. Nos. 21, 26. 1881. C, I.

As inefficient in—

1878. No. 25. 1879. Nos. C, 33, 35, 36, 37. 1880. Nos. 22, 23, 25. 1881. No. M.

Nitrogen.—This may be taken as the regulating ingredient in the following experiments:

1878. No. 25. 1879. No. 36. 1880. No. 25. 1881. No. M.

As more or less efficient in—

1878. Nos. 27, 28, 29, 30, 31, 32, 33. 1879. Nos. 27, C, 29, 30, 31, 34, 35. 1880. Nos. 21, C. 1881. Nos. C, I.

As inefficient in—

1878. No. 26. 1879. Nos. 33, 37. 1880. Nos. 22, 23, 26. 1881. None.

The above data may be tabulated thus:

Effects of the fertilizing materials upon potatoes.	Superphosphate.				Muriate of potash.				Nitrate of soda.			
	Regulating ingredient.	More or less efficient.	Inefficient.	Total.	Regulating ingredient.	More or less efficient.	Inefficient.	Total.	Regulating ingredient.	More or less efficient.	Inefficient.	Total.
In nine experiments of 1878	3	5	1	9	5	3	1	9	1	7	1	9
In ten experiments of 1879	6	2	2	10	3	2	5	10	1	7	2	10
In six experiments of 1880	3	1	2	6	1	2	3	6	1	2	3	6
In three experiments of 1881	2	1	....	3	....	2	1	3	1	2	....	3
In twenty-eight experiments of 1878–'81	14	9	5	28	9	9	10	28	4	18	6	28

EFFECTS OF THE DIFFERENT INGREDIENTS IN SELECTED EXPERIMENTS.

The experiments from which the above figures have been taken were conducted under all the varying conditions to which plants are subjected in ordinary culture. Many of them were, of course, affected by weather, tillage, physical properties of the soil, and other conditions, in such ways as to materially disturb the normal action of the ingredients. And, further, the irregularities of the soil in many cases were such that generalizations could be based only upon averages of large numbers.

Accordingly my assistant, Mr. Voorhees, has gone over the tables, selected the experiments which were, according to the reports, comparatively free from the disturbing influences of drought, cold, &c., and whose results were reasonably uniform, and from these has prepared what we have called a selected table of differences. (Table XI of the Appendix.)

EFFECTS UPON CORN.

The results, taken from this table, as before, may be stated thus:

1. *Phosphoric acid* may be regarded as the regulating ingredient in the following experiments: Nos. B, 3, 8, 12, C, 7, 14, C, 80, 11, 15, 19, C, 81.

As more or less efficient in Experiments D, 9, 6, F, 22, H, O.

As inefficient in Experiments Nos. 4, E, 25, K, L.

2. *Potash* as the regulating ingredient in the following experiments: Nos. D, 4, 9, 6, F, 22, E, H, O.

As more or less efficient in Experiments Nos. B, 12, 7, 14, 11, 15, C, 81.

As inefficient in Experiments Nos. 3, 8, C, 25, K, C, 80, 19, L.

3. *Nitrogen* as the regulating ingredient in the following experiments: Nos. 25, K, L.

As more or less efficient in Experiments Nos. D, 4, 9, 12, 6, 14, 22, 19.

As inefficient in Experiments Nos. B, 3, 8, C, 7, F, E, C, 81, 11, 15, H, C, 81, O.

The above figures may be tabulated as follows:

Effects of the fertilizing materials upon corn.	Superphosphate.				Muriate of potash.				Nitrate of soda.			
	Regulating ingredient.	More or less efficient.	Inefficient.	Total.	Regulating ingredient.	More or less efficient.	Inefficient.	Total.	Regulating ingredient	More or less efficient.	Inefficient.	Total.
In twenty-four experiments.	12	7	5	24	9	7	8	24	3	8	13	24

EFFECTS UPON POTATOES.

1. *Phosphoric acid* may be taken as the regulating ingredient in the following experiments: Nos. 27, 33, 31, 1879, 21, C, 1881, and I.

As more or less efficient in Experiments Nos. 26, 28, 29, 31, 34, C, 1880.

As inefficient in none.

2. *Potash* as the regulating ingredient in the following experiments: Nos. 26, 28, 29, 31, 1879, 34, C, 1880.

As more or less efficient in Experiments Nos. 27, 33, 21, C, 1881, I.

As inefficient in none.

3. *Nitrogen* as the regulating ingredient in none.

As more or less efficient in Experiments Nos. 27, 28, 29, 31, 33, 31, 1879, 34, 21, C, 1880, C, 1881, I.

As inefficient in No. 26.

Or, tabulating as before, we have:

Effects of the fertilizing materials upon potatoes.	Superphosphate.				Muriate of potash.				Nitrate of soda.			
	Regulating ingredient.	More or less efficient.	Inefficient.	Total.	Regulating ingredient.	More or less efficient.	Inefficient.	Total.	Regulating ingredient.	More or less efficient.	Inefficient.	Total.
In twelve experiments...	6	6	0	12	7	5	0	12	0	11	1	12

It is a very striking fact that the potatoes should have responded well to the three ingredients in nearly every case where drought or other untoward conditions did not interpose.

This particular part of the discussion will be resumed further on. Meanwhile we may devote a few words to the relations of corn to the nitrogen supply.

RECAPITULATION OF THE EFFECTS OF NITROGENOUS FERTILIZERS UPON CORN.

Estimating a bushel of corn, with its cobs and stalks, to contain 1⅓ of nitrogen, and to be worth 80 cents, the effects of the nitrogenous fertilizers in the special and in the general experiments may be summarized as follows, remembering that the superphosphate and potash salt, "mixed minerals," supplied the amounts of phosphoric acid and potash in a crop of not far from 55 to 60 bushels, which would also contain about the 72 pounds of nitrogen.

Average results of experiments with corn in 1878, 1879, 1880, *and* 1881.

[Bushels of corn and pounds of nitrogen in crop per acre.]

	Corn.	Nitrogen.
Eighteen special experiments.	*Bushels.*	*Pounds.*
"Mixed minerals" alone	43.0	60.4
Same +24 pounds nitrogen	48.4	72.7
Same +48 pounds nitrogen	48.8	73.8
Same +72 pounds nitrogen	49.6	75.6
Seventy-five general experiments.		
"Mixed minerals" alone	43.4	57.6
Same +24 pounds nitrogen	47.8	63.7

In the general experiments of the mixture of 300 pounds of superphosphate and 200 pounds muriate of potash brought, on the average of fifty-three experiments, about 43½ bushels of shelled corn per acre. The special experiments, however, seem to me a fairer test of what the fertilizers may do, because, while made in all sorts of weather and on worn-out soils, they were nearly all on soils and in latitudes fit for corn, as many of the general experiments were not. In these the mixture of 300 pounds of superphosphate and 150 pounds of potash salt, which can be bought for $8.25, brought, on the average, 43 bushels of shelled corn per acre. Omitting Mr. Newton's experiment (Appendix, Tables I and III), the results of which are very exceptional, the average is 44½ bushels.

The experiments of the four seasons bear almost unanimous testimony to two things: The corn was helped but little by nitrogen in the fertilizers; and it gathered a good deal from natural sources. The increase of crop and of nitrogen in the crop will appear more clearly if we look at it another way:

Date.	In number of trials.	With nitrogen. Amount per acre.	With nitrogen. Contained in crop of—	The average increase of corn was—	The increase of nitrogen in the crop was—
		Pounds.	*Bushels.*	*Bushels.*	*Pounds.*
1877–'78	29	24	18	5.9	7.9
	15	48	36	7.6	9.1
	6	72	54	9.3	12.4
1879	26	24	18	5.9	7.9
	14	48	36	1.9	2.5
	6	72	54	0.3	0.4
1880	20	24	18	0.6	0.8
	24	48	36	9.0	12.0
	10	72	54	14.3	19.0
1881	20	24	18	1.9	2.5
	23	48	36	3.1	4.1
	20	72	54	5.0	6.7
1877–'81	95	24	18	3.6	4.8
	76	48	36	5.3	7.1
	42	72	54	6.6	8.8

Or, considering the nitrogen as paying for itself when the value of the increase of crop that came with its use equaled or exceeded the cost of the nitrogen, and expressing the results in dollars and cents:

Date.	In trials, total number.	With nitrogen am'nts.	Costing.	The nitrogen paid for itself in trials—	The nitrogen failed to pay for itself in trials—	The average loss in the several trials was—
		Pounds.				
1877–'78	29	24	$5 50	8	21	$0 90
	15	48	11 00	1	14	4 45
	6	72	16 50	None.	6	8 51
1879	26	24	5 50	5	21	90
	14	48	11 00	1	13	8 48
	6	72	16 50	None.	6	16 26
1880	20	24	5 50	4	16	2 34
	24	48	11 00	9	15	6 04
	10	72	16 50	2	8	10 10
1881	20	24	5 50	4	16	3 98
	23	48	11 00	2	21	8 52
	20	72	16 50	2	18	12 50
1877–'81	95	24	5 50	21	74	2 62
	76	48	11 00	13	63	6 76
	24	72	16 50	4	38	11 22

The only cases in which the largest rations were profitable were in the experiments of Mr. Newton.

The above calculations of pecuniary loss and gain of course apply only to those regions where corn is dear. But even at these rates the nitrogen increased the crop enough to pay its costs in only 38 trials out of 213. The pecuniary loss rose and fell with the amount of nitrogen used. With mineral fertilizers alone the crop gathered, by the above estimates, some 60 pounds of nitrogen per acre.

The important fact, however, is this: The corn plant has in these trials shown itself capable of getting on and bringing fair yields with small amounts of the less costly mineral fertilizers, even in the worn-out soils of the Eastern States. With this help it has gathered its nitrogen from natural sources, and holds it readily to be fed out on the farm and returned in the form of manure for other crops. In other words, the experiments thus far imply that corn has, somehow or other, the power to gather a great deal of nitrogen from soil or air, or both; that in this respect it comes nearer to the legumes than the cereals; that, in short, corn may be classed with the "renovating" crops. If this is really so, and this can be settled only by continued experimenting, then our great cereal, instead of being simply a consumer of the fertility of our soils, may be used as an agent for their restoration.

THE DOMINANT FERTILIZING INGREDIENTS.

The experiments and the theory of M. Ville.—It will be interesting to note in how far the theory of "dominant ingredients" is borne out by

the experiments. According to Ville the "dominant" for corn is phosphoric acid.

The effects of nitrogen, phosphoric acid, and potash are very clearly shown above, in the discussion of the "table of differences." As there shown (see Tables X and XI of the Appendix and the recapitulation above), in some of the experiments the phosphoric acid was a decidedly regulating ingredient, the corn respond uniformly to it, and pay comparatively little attention to the others. In others the superphosphate, though not holding so important a place, was more or less useful. In still others the superphosphate produced little or no effect, the average increase of the several plots in each experiment being less than 4 bushels per acre. In like manner the potash was occasionally, though less often, the regulating ingredient. Often it had a considerable effect, but as often produced no marked results. The nitrogen may be regarded as the regulating ingredient in only a very few trials, and of these nearly all were in a single field, in which the experiments of Mr. Newton were made.

In brief, phosphoric acid took the leading place often, potash occasionally, and nitrogen very rarely. In bad seasons, and on some soils in good seasons, neither material had any effect. The most effective ingredient depended upon soil and season.

IS CORN IN ITS RELATIONS TO NITROGEN MORE CLOSELY ALLIED TO THE CEREALS OR THE LEGUMES?

In relation to this question I can do no better than repeat what was said in a previous report:

> Our experiments imply that corn shares, to a considerable extent, the power of the legumes for gathering nitrogen from natural sources. One thing, however, detracts from their decisiveness. Most of the trials were on old grass land which contained large quantities of roots on which the corn doubtless fed. How well it could provide itself with nitrogen from nitrogen compounds in the soil and from air without the roots to feed upon is not settled.
>
> The experiments are numerous and decisive enough to warrant the inference that, as corn is commonly grown, nitrogenous fertilizers in any considerable quantity would be rarely profitable. They imply that corn has somehow or other the power to gather a great deal of nitrogen from soil or air, or both; they imply that in this respect it comes closer to the legumes than the cereals—that, in short, corn may be classed with the renovating crops.

THE FEEDING CAPACITIES OF POTATOES AND OTHER PLANTS.

Our experiments throw some light upon this question, as may be seen especially in Tables X and XII of the Appendix. Thus, in the experiments of Mr. Bartholomew, detailed in No. C of Tables I and II, corn and potatoes were grown side by side under precisely similar treatment.

The corn paid scarcely any attention to the potash and very little to the nitrogen, but responded largely to the phosphoric acid. The potatoes, on the contrary, were helped in a very marked degree by superphosphate and potash salt, and by nitrogen in all its forms—nitrate of

soda, sulphate of ammonia, dried blood, the mixture of all these, and Peruvian guano. Experiments on adjacent fields have brought exactly concordant results. In Mr. Bartholomew's four years' experimenting both crops have uniformly responded to phosphoric acid; but, while corn has paid little heed to nitrogen in commercial fertilizers in any form, and almost none to potash, potatoes have as regularly responded to both.

Similar results may be observed in the experiments of Mr. Benson in Tables VI and VII of Appendix, and Professor Jordan (Tables I and VII), in which corn and potatoes were grown side by side. In the experiments of Mr. Fairchild, also, which are detailed in the tables, corn and potatoes have both responded to all three ingredients. But while the corn has paid but little heed to potash, scarcely any to nitrogen, the potatoes have been largely benefited by both.

If potatoes get so much help from nitrogen and potash in Mr. Bartholomew's land, where corn can provide itself with these materials without aid from fertilizers, it would seem fair to expect them to respond to the same materials in almost any place where weather and other circumstances favor their growth. Exactly this is the case in the experiments in general, as may be seen by reference especially to Tables X and XI, and the recapitulation of the figures in the discussion above.

In brief, the results obtained each successive season confirm the statement made in a former report, that—

Taking all in all, the potatoes responded to the superphosphate, potash salt, and nitrogenous fertilizers in almost every case where the weather permitted fair growth. None of the other crops except, perhaps, turnips have shown such uniformly beneficial results from all the materials.

The experiments indicate very decidedly that the potato plant differs from many others in respect to the effect of these fertilizing materials upon its growth, and imply that it has less capacity than corn for gathering an adequate supply of food from natural sources. It seems to demand a full and immediately available supply of nourishment for its successful growth.

Concerning the other crops, the data at hand are too meager to warrant any general conclusions. * * * In general, however, the experiments accord with the common notion that makes superphosphate almost a specific for turnips. But they imply that even when the superphosphate is supplied in abundance, the turnip is not usually able to gather enough of the other materials for a full yield unless they are close at hand in readily available forms.

THE TEACHING OF THE EXPERIMENTS REGARDING FORMULAS FOR FERTILIZERS.

Ville's formula for an acre of corn, as explained above, is as follows:

Materials.	Ingredients.	Cost in formula.	In cheapest form.
Nitrate of potash, 180 pounds	Nitrogen, 24 pounds	$9 20	$4 60
Acid phosphate of lime, 540 pounds	Phos. acid, 81 pounds	9 45	9 45
	Potash, 79 pounds	7 00	3 56
Sulphate of lime, 360 pounds		1 44	1 44
		27 09	19 25

The prices of the valuable ingredients are stated both as M. Ville recommends and as they may be bought in the equally good and cheaper materials, like nitrate of soda, guano, bone, and potash salts, which, with many important facts in agricultural chemistry, his system curiously ignores.

It is questionable whether so much of superphosphate or plaster as this formula requires would be often profitable. In the experiments potash was frequently, and nitrogen in small quantities occasionally, profitable, but the idea of using such a costly material as nitrate of potash to furnish them is economically absurd.

As long as soils and seasons continue to differ, then formulas to fit all cases are simply out of the question. At the same time there are many cases in which a man does not know what his soil requires, and can better afford to use a complete fertilizer, and pay the penalty of his ignorance in the purchase of superfluous materials, than to run the risk of losing his crop. Formulas are irrational, but they mark the first step in the progress toward rational fertilization.

THE EFFECTS OF NITROGEN IN DIFFERENT FORMS OF COMBINATION.

In comparing the effects of nitrogen in the forms of nitric acid, ammonia, and organic nitrogen, I had expected to find some marked differences; enough, perhaps, at least, to show a balance in favor of one or the other; but a careful study of Table XII of the appendix, where a very considerable number of comparative trials are averaged together, fails to show any marked excess of yield by either, in the experiments with either corn or potatoes. Those with the other crops have been too few to warrant any generalization.

FURTHER SUMMARY OF EFFECTS OF INGREDIENTS OF FERTILIZERS.

I give further results of the experiments as shown by the tables in the appendix, especially the "tables of difference," Tables X and XI of the appendix.

1. In a report of the experiments of 1878 it was stated that: The effects of the different materials on the poorer soils were generally very uniform. On the better soils they were more varied. This fact supports the view that the experiments are generally reliable as tests of the wants of worn-out soils, those which have only their natural strength to rely upon; but are not to be depended upon for rich soils, those that have an accumulated store of plant-food to draw from.

2. It is commonly stated that superphosphates, potash salts, and other like materials are more effective when used together than separately. That complete fertilizers are more reliable and effective than partial fertilizers is very certain. But if it is meant that the increase from the use of a given material, as potash salt, is greater when it is applied with other fertilizers than when it is used alone, the assertion

s not supported so decidedly by these experiments. Still, on the whole, he balance is in favor of the use of mixtures. This has been especially rue in the experiments with potatoes. Here nitrate of soda, superhosphate, and muriate of potash have each been much more efficient n the complete fertilizer than alone or in the partial fertilizers.

3. NITRATE OF SODA was most effective where used in connection vith other materials on potatoes. Alone on potatoes, and either alone r with other materials on corn, it was generally unprofitable, though n a few cases the results are very striking. As regards the other crops, he data are insufficient for generalization.

4. SUPERPHOSPHATE.—Superphosphate has proved profitable for orn usually, and for potatoes in every case where bad weather and ther untoward circumstances did not interfere. It has been most useful n the poorer and medium soils. With corn on the rich soils it has had ess and sometimes almost no effect.

5. PLASTER.—The effect of the plaster has been extremely variable; ometimes quite unpronounced, and sometimes very marked.

6. MURIATE OF POTASH proved profitable with corn very frequently; with potatoes in nearly every case where not interfered with by bad weather and other disturbing causes. Contrary to the common doctrine, potash salts did not prove more efficient with other fertilizers than when used alone, though, of course, the best results were obtained when it was used with other fertilizing materials. It is noticeable that in cases of drought, or where the fertilizers were applied in the hill or drill, both muriate of potash and nitrate of soda were often injurious. With the mixture, too, this was especially the case.

THE EFFECTS OF FERTILIZERS ON THE DIFFERENT KINDS OF SOIL.

I think that the more carefully the tabular statement of the results are studied the more correct will the following statement, from one of the reports of experiments above referred to, appear:

> Indeed, without more and more definite data than are given by these or any other field experiments I have ever known of, I see no prospect of getting at any reliable generalizations as to the kinds of soils on which such fertilizers are or are not beneficial. The fact is that the circumstances of composition, texture, absorptive power, and relations to moisture and heat of the soils, of climate and season, of previous tillage, manuring, and crops are so complex and variable that no such empirical experiments as it is possible to carry on in field culture can bring full and definite information as to the ways in which soils and fertilizers supply food to plants or otherwise affect their growth. These problems must be also studied by the more accurate methods and with the control of conditions which are possible only in culture on a small scale, in the greenhouse or garden, and with the appliances and help of the laboratory.

EFFECTS OF THE DIFFERENT FERTILIZERS UPON THE QUALITY OF THE CORN.

In an account of the experiments in the report of Connecticut Board of Agriculture for 1880, some statements were given respecting the

effects of the different fertilizers upon the quality of the corn, and the ratio of stalks to grain. It seemed worth while to collate the figures, if for no other purpose than to test the correctness of the theories often broached respecting the effect of nitrogen, phosphoric acid, potash, &c., upon the crop. As will be seen from the following extract from the report referred to, no very definite theory is borne out by the experiments. It has not seemed to me, therefore, worth while to carry the computations into the experiments of 1881.

The effects of the different fertilizers on the proportion of good to poor corn, and of corn to stalks, are worth noting. A number of experimenters reported the amounts of "good" and "poor" corn. The percentages of "good" corn, *i. e.*, the number of pounds in 100 pounds total corn as reported by the experimenters, are:

Number of pounds of good corn in 100 *pounds of total corn, with the different fertilizers.*

Number of experiment.	O. Nothing.	A. Nitrogen.	B. Phosphoric acid.	C. Potash.	D. Nitrogen and phosphoric acid.	E. Nitrogen and potash.	F. Phosphoric acid and potash.	G. Nitrogen, phosphoric acid, and potash.	H. Plaster.	Farm manures.
2	49	49[6]	68[5]	53[5]	69[4]	60[3]	68[7]	[5]	[5]	.....
3	69	78	86	83	60	88	63	88	85	.....
5	61	71	55	77	84	80	86	90	56	[illegible]
8	62	67	84	75	85	53	76	63	58	.....
9	69	74	74	63	78	.....	79	79	54	.....
10	80	72	93	70	87	62	91	92	89	.....
12	.....	80	83	80	87	83	93	92	90	.....
13	88	87	91	88	92	82	94	94	.....	.....
14	87	89	87	77	80	80	86	86	90	[illegible]
17	95	93	97	98	99	99	99	98	99	.....
19	97	97	97	97	98	97	98	99	97	.....
20	95	95	94	92	97	95	97	97	97	.....
Average of twelve experiments in 1880	71	79	84	79	85	79	86	88	82	[illegible]
Average of fourteen experiments in 1879	56	58	72	62	73	64	61	69	63	[illegible]
Average of eight experiments in 1878	65	67	72	80	72	86	86	85	73	[illegible]
Average of thirty-four experiments in 1878–'80	63	68	76	72	77	74	76	79	72	[illegible]

The figures accord with the common experience that the largest yield gives also the largest proportion of good corn. Otherwise, no relation between the fertilizers and the proportions of good and poor corn is discoverable.

RATIO OF STALKS TO SHELLED CORN.

The weighings of corn and stalks were made at different stages of dryness. In some cases the stalks were cut above the ears, in others close to the ground. The results are consequently discrepant. The averages are interesting as showing the relative effects of the fertilizing materials.

Number of pounds of stalks to 100 pounds of shelled corn.

Number of experiment.	O. Nothing.	A. Nitrogen.	B. Phosphoric acid.	C. Potash.	D. Nitrogen and phosphoric acid.	E. Nitrogen and potash.	F. Phosphoric acid and potash.	G. Nitrogen, phosphoric acid, and potash.	H. Plaster.	Farm manure.
2	464	423	115	127	240	151	288	.....	.....	....
3	390	228	145	219	406	182	571	291	305	....
4	168	199	92	175	158	159	159	170	158	126
5	118	98	126	123	108	121	154	131	150	85
8	93	86	65	104	91	108	98	130	107	....
9	102	198	96	101	97	.....	92	102	99	....
13	129	111	111	147	108	168	124	122	.....	....
14	81	122	94	174	94	163	175	174	89	130
16	196	99	106	103	95	83	91	94	101	....
18	118	108	112	116	108	111	109	129	106	....
Average of ten experiments in 1880	186	159	106	139	151	138	186	149	142	114
Average of twelve experiments in 1879	149	156	120	168	105	162	141	124	219	115
Average of ten experiments in 1878	173	143	149	145	129	176	128	131	139	183
Average of thirty-two experiments in 1878–'80	168	158	125	151	127	158	150	133	172	122

The proportion of stalks to shelled corn is smaller in the larger crops, and conversely the poorer crops have more stalks for the same amount of corn than the better crops. Contrary to what is commonly supposed, the nitrogenous fertilizing materials do not seem to have increased the amount of stalks as compared with corn.

MODE OF APPLYING THE FERTILIZERS, WHETHER BROADCAST OR IN THE HILL OR DRILL.

The following is from an account of the experiments in one of the Connecticut reports referred to:

The testimony of the experiments is on the whole against applying in the hill or drill. The best results in the majority of cases came where the fertilizers were sown broadcast. Several of the very best were where the materials were scattered over a strip a couple of feet or so wide along the rows. Many of the worst results were where the fertilizers were put in the hill or drill. The nitrate of soda and potash salts thus applied often injured the crops, especially in dry weather. The following from the directions for the experiments is not out of place here:

"The fertilizers may be applied broadcast, or, if more convenient, they may be put in the hill or drill, *provided they are well diffused through the soil.* To accomplish this, they had better be diluted with several times their bulk of earth before using. The important points are, that they be—

"1st. Applied evenly over the plots where they belong and not allowed to get outside.

"2d. Well distributed through the soil.

"Experiments with concentrated fertilizers are often spoiled, just as crops are injured or lost through wrong application. Farmers are apt to think that the manure must be put close to the seed or the plant will not get the benefit of it. This is wrong. It is not the just germinated plantlet that needs the manure, but the plant, from the time it is well started until its growth is done. We want, not only to give the crop a good start, but to help it out on the home stretch as well. The roots and their branching rootlets run out in all directions in search of food, and the fertilizers ought

to be where as many of the rootlets as possible can get at them. If we distribute the fertilizers as well as we can, the water in the soil, aided by the chemical and physical forces that nature keeps in operation, will do the rest. In illustration of this remember how well barn-manure acts when applied as a top-dressing long before the seed is put in.

"But if we concentrate the fertilizers in one place fewer roots will get them, and these may be injured by coming in contact with them or with their concentrated solutions in the soil. The roots will find their way to the manure and develop more where it lies, it is true, still we should not oblige them to huddle together in one place, but should rather encourage them to spread around, where, with the increased capacity the fertilizer gives them, they can get the more from the soil. Roots join with other natural agents in rendering inert stores of plant food available.

"Above all, do not let the fertilizers come too close to the seed. A coarse, dilute material like yard manure may do the plants no harm, but such concentrated fertilizers as potash salts, dried blood, nitrate of soda, or high grade superphosphates may kill them."

CHEMICAL FERTILIZERS VS. FARM MANURES.

Of course no fair comparisons can be made between the artificial fertilizers whose composition was definite and constant, and the farm manures whose amount and quality were so variable and uncertain. It seems fair to presume, however, that the men who make these experiments would apply liberal doses of good manure on the small plots. The average yield and increase from the farm manures, complete fertilizer G, and mixture of superphosphate and potash salt F, in the experiments in which the farm manures were used, were as shown in the table giving averages of results of experiments of 1878 and 1881:

		Bushels per acre.		
		Farm manures.	Complete chemical fertilizer.	Mixture of superphosphate and potash salt.
Corn	Produce	45.3	47.7	41.8
	Increase	20.5	22.9	17.0
Potatoes	Produce	130.1	154.6	128.9
	Increase	58.0	82.5	56.8
Turnips	Produce	374.0	501.0	401.0
	Increase	129.0	256.0	156.0

The following statements, from the Connecticut report referred to, are in place here:

The yield and increase of corn, potatoes, and turnips were much larger with the complete chemical fertilizer than from the farm manures. The mixture of superphosphate and potash salt excelled the farm manures with potatoes and turnips, and fell slightly behind them with corn.

Concerning quality of crop, as previously stated the few experimenters who reported definitely pronounced in favor of the chemicals, especially for potatoes, which they say are smoother and less disposed to rot with the chemicals than with the farm manures.

In very many of the cases where the weather was reported especially unfavorable on account of excessive cold, wet, or drought, the chemicals have brought better

yields than the farm manures. Farm manures have the advantage over chemical fertilizers in that their organic matter tends to improve the mechanical condition of soils, counteract drought, and aid in rendering soil-food available, and perhaps to facilitate the assimilation of atmospheric nitrogen also. Concentrated fertilizers have the advantage of supplying the food in readily available forms, while they also aid in improving the texture of the soil and setting plant-food free in various ways not fully understood.

Mr. Lawes, of Rothamsted, says that to get large crops he would use artificial fertilizers rather than farm manures. Ville claims like superiority for the chemicals, and cites averages of some hundreds of experiments in proof. But I have always felt a little skeptical, and must confess that, especially in view of the small quantity of chemicals used in these experiments, the heavy balance in their favor, even in bad weather, has surprised me.

As to how the after effects of the two classes of materials will compare the future must decide. I should expect the farm manures to be more lasting. Speaking roughly, the mixture of superphosphate and potash salt contains about as much of the mineral elements of plant-food as eight or ten tons of good, well-cured stable manure. The complete fertilizer contains also about one-third or one-fourth as much nitrogen as the same quantity of manure. The bulk of the phosphoric acid and potash of both will stay in the soil until removed by plants. The nitrogen is exposed to more or less rapid loss by entering into insoluble compounds in the soil, by leaching away beyond the reach of plants, and by escaping as free nitrogen into the air. It would seem fair to expect that the effect of a dressing of stable manure, with its slower action and larger proportion of nitrogen, would last longer than the chemicals.

PRACTICAL APPLICATIONS.

The general results of the experiments taken together may be summed up nearly as follows:

1. It must be remembered that the trials were not only subject to all the vicissitudes of the weather and season, heat and cold, heat and drought, but were made on soils of all sorts, mostly very poor. The directions were to select worn-out soils, and often they were ill-adapted to the crops grown upon them; hence the average results with a given crop do not fairly represent what might be expected under favorable conditions and on soils adapted to its growth.

2. The largest yield came with the "complete" chemical fertilizer (*G*) (see "description of general experiments," and Tables IV and IX of Appendix), which supplies 150 pounds of nitrate of soda, 300 pounds of superphosphate, and 150 to 200 pounds of muriate of potash, at a cost of a little over $15 per acre.

No. G has brought by far the best results. It was generally the most profitable of all with potatoes, and often so with corn and other crops. This mixture has not only brought larger yields than the farm manures, but has also proved more certain, in favorable seasons and in cold, wet, and drought. I would not propose these proportions for general use, however. Less potash and more nitrogen would often be better, especially for grain, potatoes, and garden vegetables. The object here was to test soils, and not to get the largest possible yields.

3. The next largest average yield is with the farm manures. Then

follows the mixture of superphosphate and muriate of potash (*F*). This latter averaged most profitable of all for corn.

4. Next came the mixture of nitrate of soda and superphosphate (*E*). That this, which contained superphosphate and nitrate of soda, should bring a lower average yield than the mixture of superphosphate and potash salt with every crop on which the number of trials is large enough to warrant any general conclusions, is certainly a significant fact. Our ordinary guanos, ammoniated superphosphates, and fish manures contain (like *E*) nitrogen and phosphoric acid with a little or no potash. Nitrogen is the costliest, and potash one of the cheaper, of the valuable ingredients of ordinary fertilizers. Continued experience emphasizes the statement that manufacturers and users of ammoniated superphosphate would do well to consider the propriety of either adding potash salts or substituting them for nitrogenous materials in their fertilizers. Indeed, I see many are doing so.

5. The mixture of nitrate of soda and potash salt was the least efficient of all.

6. As to the efficiency of the materials separately, the nitrate of soda was rarely, the sulphate of lime frequently, the muriate of potash very often, and the superphosphate generally, useful. Doubtless considerable of the effect of the superphosphate was due, in many cases, to the sulphuric acid and lime.

7. The results with ashes are variable, though, generally speaking, they have been efficacious.

8. One of the chief defects of these experiments is that so few parallel trials with lime have been made. There are many cases in which a dressing of lime is the cheapest and best means of improving the land.

ARTIFICIAL FERTILIZERS VS. FARM MANURES.

9. Not only did the complete chemical fertilizer bring a larger average increase than farm manures as actually used, and the mixture of superphosphate and potash salt nearly as large, but the quality of the crop was generally better with the chemicals. Potatoes especially were finer in quality and less disposed to rot with the artificial fertilizers than with the farm manures.

AS TO THE EFFECT OF THE FERTILIZERS UPON DIFFERENT CROPS.

10. Potatoes and turnips responded most profitably to the complete fertilizer in nearly every case. Corn, on the other hand, was largely helped by the superphosphate and potash salt, but received but little benefit from the application of nitrogen in any form.

AS TO THE FEEDING CAPACITIES OF THE CROP.

11. The experiments imply that corn, somehow or other, was able to gather a fair supply of nitrogen from natural sources provided it had

enough of the mineral ingredients at its disposal. They do not tell how much of the nitrogen came from the roots of preceding crops, how much from other nitrogen compounds in the soil, and how much from the air. They imply that the potato possesses in far less degree than corn the power of gathering sufficient supply of either nitrogen or the other ingredients of its food from soil and air. They imply that turnips are generally unable to provide themselves with phosphoric acid from the soil, and are greatly helped by it in fertilizers; that without an abundance of phosphoric acid they get but little good from other materials; that with it they can gather a partial supply of the other materials of their food, but that for a full yield considerable quantities of all the soil ingredients of plant-food are needed close at hand and in available forms. Except on corn and potatoes, however, the experiments are still too few for reliable inferences.

OTHER CONDITIONS AFFECTING THE ACTION OF FERTILIZERS.

12. The most profitable material in a given case is that which is best fitted to its needs. The chief factors of the problem are:

First, soil.

Second, climate and season.

Third, feeding capacity of crop.

Fourth, form of combination of the ingredients of the fertilizer.

Fifth, the indirect action of the fertilizer, *i. e.*, its effect upon the texture of the soil; upon its power to absorb and retain plant food; in setting other plant food free.

Sixth, the composition of the plant.

Soils vary in respect to the *plant food* they supply in available forms. Phosphoric acid is most often deficient; next come potash and nitrogen; then lime and sulphuric acid, and rarely magnesia.

But the infertility of soils is due to other causes perhaps nearly as often as to lack of plant food. Soils often do not have the proper texture—they are too compact or too loose; or they are too shallow; or they lack absorptive power—they cannot retain the plant food until plants use it, but suffer it to be leached away by drainage water; or the moisture supply is bad—they are too wet or too dry. These defects are as fatal as lack of plant food. Many soils need amendments first and then manure.

Climate and season counts for much, often for everything, in the action of manures. This fact is certain. Of the reasons we know, as yet, but little.

As to effects of the *forms of combination*, nitrogen seems to do better in materials that contain it in several forms, as Peruvian guano, or a mixture of nitrate of soda, sulphate of ammonia, and dried blood, than in either of the latter substances singly. The effects of phosphoric acid and potash in different forms were tested in too few cases to warrant any conclusions.

As to the *indirect action* of fertilizers in improving the texture of the soil and setting its plant food free, the experiments have nothing to say, but we know that it often makes a large part of the usefulness of the fertilizer.

THE BEST FERTILIZERS FOR DIFFERENT CROPS.

13. It is perfectly evident, therefore, that there is no *best* fertilizer for any crop, and that formulas to fit all cases are out of the question. There are many cases, however, in which complete fertilizers are in place. There are also many in which the farmer does not know what his soil and crops need, and can better afford to pay for some unnecessary materials in a complete fertilizer than to risk the loss of his crop. But for this demand dealers offer a supply. Instead of proposing formulas, I urge farmers to study their soils and circumstances and learn what is best for them to use.

14. The common impression among farmers that the best use of artificial fertilizers is to supplement farm manures is doubtless, in ordinary circumstances, correct.

15. Leaving variations in soil and season out of account, and considering the feeding capacity of the crops, as shown by these and other experiments and by general experience, it is safe to say that—

(1) For *corn*, an excellent fertilizer to bring large crops would be a mixture of some material containing nitrogen and phosphoric acid, as Peruvian guano, or fish guano, and muriate of potash. To this it might be profitable to add some fine-ground bone or superphosphate. In the majority of cases, though not always, a more profitable mixture would probably be one of muriate of potash, with either superphosphate or fine-ground bone, or both. At the same time there are cases in which nitrogen helps the crop enough to make it profitable, and in which nitrate of soda, sulphate of ammonia, dried blood, guano, or fish, would be in place.

(2) For *potatoes*, which respond more generally than corn to both nitrogen and potash, such of the above mixtures as contain considerable nitrogen would generally be in order.

AS TO COMMERCIAL FERTILIZERS IN GENERAL.

16. For general farming, at a distance from the large markets, the chief use of commercial fertilizers should be to supplement the manure of the farm. The right way is to make the most and best manure that is practicable upon the farm, and piece out with such commercial fertilizers as experiments and experience prove profitable. At the same time there are many cases, especially near cities, where everything depends upon getting the largest and best yield, and where more exclusive use of chemical fertilizers is advisable.

IN CONCLUSION.

Taken all together, the experiments emphasize more and more strongly, year after year, the conclusions expressed in previous reports that:

17. Soils vary widely in their capacities for supplying crops with food, and consequently in their demand for fertilizers.

18. Some soils will give good returns for manuring; others, without previous amendment, by draining, irrigation, tillage, or use of lime, marl, &c., will not.

19. Farmers cannot afford to use commercial fertilizers at random, and it is time they understood the reason why.

20. The right materials in the right places bring large profits. Artificial fertilizers, rightly used, must prove among the most potent means for the restoration of our agriculture.

21. The only way to find what a soil wants is to study it by careful observation and experiments.

PLANS FOR CO-OPERATIVE EXPERIMENTS.

The report of proceedings of a convention held at the Department of Agriculture contains a paper on the subject of Co-operative Experiments as a Means of Studying the Effects of Fertilizers and the Feeding Capacities of Plants.

With a special issue of this address, published by the department, were given some suggestions for experiments which it seems proper to reproduce here:

In organizing a system of co-operative experimenting, the one great need is an official and influential center, whence suggestions and plans for work may emanate, and where reports of results may be collated, arranged, and published, and with whose wise aid all can work together. By the espousal of the enterprise by the Agricultural Department at Washington, under its present very efficient management, this want is most happily met. And nothing could be more auspicious for such a union between the department and the best experimenters of the country than the discussions and action of the late convention.

PLANS FOR EXPERIMENTS.

In accordance with a request from the Commissioner of Agriculture, I have undertaken, with the aid of several well-known workers in this line, to prepare some plans for experiments; doing so, however, with the feeling that what is wanted is not detailed and inelastic schedules, but rather, outlines which each experimenter can fill in as seems to him most advisable. Every man knows his own circumstances, and every intelligent worker has valuable ideas of his own, which others have not. It seems to me that the most effective system will be one which will enable each to develop his own ideas, while we all work together and contribute our results to the common fund.

KIND OF INVESTIGATIONS THAT ARE NEEDED.

To get the most complete results we need:

I. Field experiments, to include—

a. The culture of plants on plots of land treated with different manures, and careful weighings and measurements of produce.

b. Where practicable, chemical and physical studies of the soil.

c. In many cases, chemical analyses of the plants.

II. Pot experiments, in which the conditions can be definitely known and controlled, and the needed studies of soil and plants be carried out with equal or greater convenience and accuracy.

Indeed, it is safe to say that there ought to be in the various sections of the country chemical and physical surveys of the land in the behalf of agriculture, as there have been topographical and geological surveys in the behalf of other industries and interests. And in fact this is precisely the direction in which we are tending in this experimental work.

The subjects proposed at the Washington convention for co-operative experiments were:

1. The supply of nitrogen to plants.

2. The action of phosphoric acid in different forms of combination and in different fertilizing materials upon the growth of plants.

Practically, so far as field experiments are concerned, these two subjects reduce themselves to the study of the action of nitrogenous and phosphatic fertilizers

The first thing, then, will be to see what materials are to be employed.

Since similar questions regarding potash will naturally arise, it may be well to include brief suggestions regarding potassic fertilizers. Of course sulphuric acid, lime, and magnesia could be treated in like manner if it should hereafter become desirable.

QUANTITIES OF MATERIALS TO BE USED.

To decide what quantities of materials will be best for the purpose is not easy, because of the lack of the very data for which the experiments are, in part, to be made. Neither the proportions which occur in any crops, nor those in farm manures, could well serve as a standard. Probably the best plan will be to endeavor to select, as extremes, the smallest and the largest quantities that general experience has brought into ordinary use, and arrange intermediate quantities at proper intervals between.

Nitrogen.—A dressing of 450 pounds of nitrate of soda per acre is probably as large as would be apt to be used in this country, in ordinary practice, on ordinary crops. At the same time it is no more than has been found profitable in previous nitrogen experiments, and is perhaps as small as would be advisable for the maximum. At 16 per cent. it would contain 72 pounds of nitrogen.

Three hundred pounds of an ammoniated superphosphate with 3 per cent., or 9 pounds, of nitrogen, is not an unusual dressing per acre. As little as 200 pounds, with only 6 pounds of nitrogen per acre, is a common quantity for cotton, and, indeed, for other crops, when applied in the hill or drill or as a supplement to other manures. Six pounds of nitrogen is a very small quantity for an acre of land. Twelve pounds, which would be contained in 75 pounds of nitrate of soda, would seem to be little enough. Still it will be well to provide for as small an amount as is ordinarily used.

In arranging the rations it would seem best to make the difference between the smaller rations less than that between the larger ones. In the previous nitrogen experiments, three rations, "one-third," "two-thirds," and "three-thirds," with 24, 48, and 72 pounds of nitrogen per acre, respectively, have been employed. Prefacing these by a "one-twelfth" ration of 6 pounds, and a "one-sixth" ration of 12 pounds, we shall have a series of five—

Nitrogen rations.

a. One-twelfth ration: Nitrate of soda, 38 pounds, with 6 pounds of nitrogen.
b. One-sixth ration: Nitrate of soda, 75 pounds, with 12 pounds nitrogen.
c. One-third ration: Nitrate of soda, 150 pounds, with 24 pounds nitrogen.
d. Two-thirds ration: Nitrate of soda, 300 pounds, with 48 pounds nitrogen.
e. Full ration: Nitrate of soda, 450 pounds, with 72 pounds nitrogen.

Of this list, either all or part may be used. Thus on soils or for crops where smaller quantities are in place, *a*, *b*, and *c* could be employed. Where more nitrogen is

wanted, *c*, *d*, and *e* would be better. If, as is not impossible, experience should show that the smaller rations are too small to be useful, it will be a very simple matter to omit them.

Phosphoric acid.—One hundred pounds of a superphopshate with 16 per cent. P_2O_5 is as little as would be often used on an acre, while 600 pounds with 96 pounds of P_2O_5 would be a large dressing. In view of the fact that general experience has led to the employing of much larger quantities of phosphoric acid than of nitrogen, the proportions within this range would be none too large to go with those of nitrogen suggested. Doubtless a series of four rations arranged as below would suffice.

Phosphoric acid rations.

a. One-sixth ration: 100 pounds superphosphate with 16 pounds phosphoric acid.
b. One-third ration: 200 pounds superphosphate with 32 pounds phosphoric acid.
c. Two-thirds ration: 400 pounds superphosphate with 64 pounds phosphoric acid.
d. Full ration: 600 pounds superphosphate with 96 pounds phosphoric acid.

Potash.—Many of the popular fertilizing mixtures are calculated to supply very small quantities of potash, not over 17 pounds per acre, while 200 pounds of muriate of potash are often used for a dressing. Taking these as extremes and dividing as before we shall have—

Potash rations.

a. One-sixth ration: 33 pounds muriate of potash with 17 pounds potash.
b. One-third ration: 67 pounds muriate of potash with 33 pounds potash.
c. Two-thirds ration: 133 pounds muriate of potash with 67 pounds potash.
d. Full ration: 200 pounds muriate of potash with 100 pounds potash.

Putting the above forms together we have rations as follows:

	Nitrate of soda.	Superphosphate.	Muriate of potash.	Nitrogen.	Phosphoric acid.	Potash.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
One-twelfth ration	38	.....	.....	6	.....	.....
One-sixth ration	75	100	33	12	16	17
One-third ration	150	200	67	24	32	33
Two-thirds ration	300	400	133	48	64	67
Full ration	450	600	200	72	96	100

DUPLICATION OF TESTS.

A very great, if not the greatest, obstacle to the success of field experiments is the unevenness of soils. The variations in the produce of different plots of apparently uniform land under the same treatment are often very surprising. An experiment in which duplicates agree as closely as could be desired is the exception rather than the rule. Cases in which the differences between plots treated alike are greater than between those treated differently, are, if anything, more common.

To get around this difficulty, numerous devices are employed. One is to test the uniformity of the plots by treating all alike the first year, and, if they vary materially, to either attempt to average duplicates so as to make the differences counterbal ance, or to allow for the differences in computing the final results. One serious objection to either of these plans is the uncertainty as to the cause of the variation and to whether it will be constant in succeeding years.

Another plan consists in making the plots long and narrow, so as to equalize the differences. This, though often successful, is not always so. The ideal method would be to test the experimental areas by uniform treatment for a series of years until

temporary causes of irregularity, such as came from manuring, tillage, cropping, &c., were eliminated, and to use for experiment only such as prove to be intrinsically uniform.

Where feasible, this latter plan is certainly to be recommended. But if we are to begin an experiment at once, doubtless the best way is to use small plots and duplicate the trials by using the same materials on several. This duplicating will test the uniformity and reliability of the whole experiment, and give averages which, when no untoward circumstances prevent, are pretty sure to be fairly satisfactory and are often perfectly so.

SIZE OF EXPERIMENTAL PLOTS.

Ordinarily, plots of eight square rods, one-twentieth acre, each, seem as satisfactory as any. In most cases, two plots of one-twentieth would be preferable to one of one-tenth acre. At least, such is the impression left on my mind after looking over the reports of several hundred experiments sent me for examination. Before this experience I was inclined to larger areas, but I have been surprised at the uniformity of small plots, when they are long and narrow. Some of the most satisfactory field experiments have been on plots of only four square rods. It is very common to leave a number of plots unmanured to test the uniformity of the soil, but it is a question whether this purpose is not better served by duplicating manured plots, and using not more than two or three unmanured for an ordinary experiment. Thus, for the nitrogen experiments, the most satisfactory plan I have found has been to leave one unmanured plot on each side of the experimental field, and to frequently duplicate the "basal mixture" of superphosphate and potash salt.

SPACES BETWEEN THE EXPERIMENTAL PLOTS.

Another frequent cause of inaccuracy in field experiments with fertilizers is the extension of the roots of the plants of one plot into the soil of the next one, so that the plants feed upon their neighbors' fertilizers. The roots of corn, for instance, extend laterally several feet, and, unless something is done to prevent, the plants may get so much material that does not belong to them as to vitiate the results of the experiments. The yield on an unmanured plot between two manured ones is often much larger than on another unmanured plot whose plants have not the fertilizers close at hand to draw upon. The best plan to obviate this is to leave unmanured strips between the experimental plot so wide that the roots will not reach across them. The difficulty can be helped, of course, by plowing between the plots deep enough to cut the roots.

NITROGEN EXPERIMENTS.

In planning these experiments we need to consider the questions to be studied, the forms and quantities of nitrogen to be used, and the most fitting arrangement for the experiments. The following details naturally suggest themselves:

A.—QUESTIONS ESPECIALLY NEEDING STUDY.

I. The action of nitrogen in different forms and amounts upon the growth of plants under varying conditions of crop, soil, climate, season, &c.

II. The feeding capacities of different plants as related to nitrogen, *i. e.*, their capacities for providing themselves with nitrogen from natural sources, and for utilizing that furnished in the fertilizers, in so far as these capacities are indicated by effects of the nitrogenous materials upon their growth.

B.—FORMS AND AMOUNTS OF NITROGEN AND NITROGENOUS FERTILIZERS.

I. The most important forms of nitrogen are:

1. Nitric acid.
2. Ammonia.
3. Organic nitrogen.

II. Among the kinds of fertilizers containing nitrogen in these forms, the following are important:

1. Nitric acid.
   a. Nitrate of soda.
   b. Nitrate of potash.
2. Ammonia.
   a. Sulphate of ammonia.
3. Organic nitrogen.
   a. Dried blood.
   b. Meat scrap.
   c. Fish scrap and fish guano.
   d. Leather scraps.

III. Quantities, as above named, to wit, "one-twelfth," "one-sixth," "one-third," "two-thirds," and "full rations," or 6, 12, 24, 48, and 72 pounds per acre.

DETAILED PLANS.

In the account of nitrogen experiments above are schedules of the kinds and quantities of fertilizing materials there employed. Judging from the results of past experience, however, those schedules would be improved by slightly altering the quantities so as to make them conform with the rations just named, and by enlarging the list of nitrogenous fertilizers to be tested.

KINDS OF NITROGENOUS FERTILIZERS.

The following will doubtless be to the purpose:

1. For nitric acid, nitrate of soda, 96 per cent. purity, with 16 per cent. nitrogen.
2. For ammonia, sulphate of ammonia, with 21 per cent. nitrogen.
3. For organic nitrogen.
   a. Dried blood (steam dried), with 11 per cent. nitrogen.
   b. Meat scrap, azotin, with 11 per cent. nitrogen.
   c. Fish guano, with 8 per cent. nitrogen.
   d. Leather scraps (finely pulverized), with 7 per cent. nitrogen.
4. For nitric acid, ammonia, and organic nitrogen together, "nitrogen mixture," consisting of nitrate of soda, 16 per cent. nitrogen; sulphate of ammonia, 21 per cent. nitrogen, and dried blood 11 per cent. nitrogen in equal parts, and containing 16 per cent. nitrogen.

QUANTITIES OF NITROGENOUS FERTILIZERS.

We may plan for each nitrogenous fertilizer a "group" with rations, as above suggested. Thus we may have nitrogen groups with quantities per acre as follows:

Nitrogen rations.

	Ration.	Nitrate of soda.		Ration.	Sulphate of ammonia.
		Pounds.			*Pounds.*
NITRATE OF SODA GROUP	One-twelfth	38	SULPHATE OF AMMONIA GROUP	One-twelfth	29
	One-sixth	75		One-sixth	57
	One-third	150		One-third	114
	Two-thirds	300		Two-thirds	228
	Full	450		Full	343

	Ration.	Dried blood.		Ration.	Nitrogen mixture.
		Pounds.			*Pounds.*
DRIED BLOOD GROUP	One-twelfth	55	NITROGEN MIXTURE GROUP	One-twelfth	38
	One-sixth	110		One-sixth	75
	One-third	220		One-third	150
	Two-thirds	440		Two-thirds	300
	Full	660		Full	450

ARRANGEMENT OF THE EXPERIMENTS.

In this way such materials as may be most desirable can be selected for each experiment, and for each a group be used with all or part of the rations suggested. Future experience must show what quantities will be best. Probably, for ordinary crops in the North, the three largest rations will be well. In the South, for cotton, very likely the smaller will be preferable. At any rate, this flexibility of plan allows fair latitude of detail, and at the same time secures the uniformity needed for the tabulation and comparison of different experiments.

In some cases it will be desirable to use the nitrogenous fertilizers alone. In the majority of cases, however, the full effect of the nitrogen will not be manifested unless some other materials are added. Generally speaking, the experiment will be most satisfactory with "complete fertilizers," such as can be made by adding the nitrogenous materials to a mixture of superphosphate and potash salt, which may be designated as "mineral fertilizers" or "mixed minerals." For these, the two-thirds rations, 400 pounds of superphosphate and 133 pounds of muriate of potash, will probably be adapted to a larger proportion of the soils and crops than the mixture of 300 pounds of superphosphate and 150 pounds of muriate of potash, used in the former nitrogen experiments. Taking the basal mixture named, and adding the several rations of nitrate of soda, we shall have a "Nitrate of Soda Group" of five mixtures, each mixture containing the "mixed minerals" with a nitrate of soda ration as below:

Nitrate of Soda Group:

Mixed minerals with nitrate of soda, one-twelfth ration.
Mixed minerals with nitrate of soda, one-sixth ration.
Mixed minerals with nitrate of soda, one-third ration.
Mixed minerals with nitrate of soda, two-thirds ration.
Mixed minerals with nitrate of soda, full ration.

The amount per acre and the percentages of the several ingredients in the nitrogen mixture group, for instance, would be as follows:

Nitrogen mixture group.	Fertilizing materials.			Ingredients.					
	Superphosphate, pounds per acre.	Muriate of potash, pounds per acre.	Nitrogen mixture, pounds per acre.	Phosphoric acid, pounds per acre.	Potash, pounds per acre.	Nitrogen, pounds per acre.	Phosphoric acid, per cent.	Potash, per cent.	Nitrogen, per cent.
One-twelfth ration	400	133	38	64	67	6	11.2	11.7	1.5
One-sixth ration	400	133	75	64	67	12	10.5	11.0	2.0
One-third ration	400	133	150	64	67	24	9.3	9.8	3.5
Two-thirds ration	400	133	300	64	67	48	7.6	8.0	5.8
Full ration	400	133	450	64	67	72	6.5	6.8	7.3

PRELIMINARY GROUP.

The experiment will be much more satisfactory if we know the effects of the superphosphate, potash, salt, and nitrogenous materials separately, and, inferentially, the capacity of the soil to supply the phosphoric acid and potash as well as the nitrogen. To this end we may use the materials separately, and two by two, as has been done in previous experiments, and is shown in the schedule beyond. In the experiments described above the nitrogen of the preliminary groups has been supplied in either nitrate of soda or "nitrogen mixture." Though experience has shown very little difference, probably the mixture will be the safer, and accordingly it is here recommended.

As urged above, the many sources of error in field experiments make duplicates very important. This may be effected by repeating the nitrogen groups, in which opportunity is taken to test the different forms of nitrogen, and by putting the mixed minerals on each side of each nitrogen group, thus testing the uniformity of the soil, replacing the unmanured plots, and showing more accurately the effects of the nitrogen.

To recapitulate briefly, our experimental fertilizers, as thus planned, will be arranged in groups, thus:

Partial fertilizers	Preliminary Group. Each by itself, and two by two.	Thus testing the effects of ingredients separately and capacity of soil to supply them.	
Complete fertilizers..	Nitrate of soda Group. Nitrogen as nitric acid in nitrate of soda.	Nitrogen in one-twelfth, one-sixth, one-third, two-thirds, and full rations.	
	Sulphate of ammonia Group. Nitrogen as ammonia in sulphate of ammonia.		
	Dried blood Group. Nitrogen as organic nitrogen in dried blood.		
	Nitrogen mixture Group. Nitrogen in the three forms named above.		

Other groups containing meat scrap, fish guano, Peruvian guano, leather scrap, &c., can be employed at the discretion of the experimenter. When desired, as may be the case with cotton, for instance, half the quantities may be used, or the same quantities distributed over double the area. The preliminary groups can be omitted if necessary, the nitrogen groups used without the basal mixture, and a smaller list of rations used in each group, as may be desirable in each case. Two nitrogen sets, which can be obtained ready for use, are described beyond.

PHOSPHORIC ACID EXPERIMENTS.

In devising plans for these experiments we have to consider what questions are to be studied and what compounds of phosphoric acid are to be employed.

A.—QUESTIONS TO BE STUDIED.

The following may be regarded, at the outset at least, as among the more important:

I. The action of phosphoric acid in different forms and amounts upon the growth of plants under different conditions of crop, soil, climate, season, &c., *e. g.*,
   1. Soluble *vs.* precipitated.
   2. Soluble *vs.* insoluble.
   3. Effects of fineness of pulverization upon the availability of insoluble phosphoric acid in bone, rock phosphate, &c.
   4. Bone *vs.* mineral phosphate.
   5. Raw bone *vs.* boiled bone; *i. e.*, bone from which gelatine has been extracted.

II. The feeding capacities of different plants as related to phosphoric acid, *i. e.*, their capabilities of availing themselves of the supplies of phosphoric acid at their disposal in the soil, and in fertilizers, in so far as their capabilities are indicated by the observed effects of the phosphoric acid compounds.

B.—FORMS AND AMOUNTS OF PHOSPHORIC ACID AND PHOSPHATIC COMPOUNDS.

The following list seems complete enough for the present purpose:

I. Forms of phosphoric acid:
   1. Soluble.
   2. Precipitated.
   3. Insoluble.

II. Kinds of phosphatic compounds:
   1. Bone.
      a. Raw.
      b. Steamed.
      c. Bone black.
      d. Bone ash.
   2. Phosphatic guanos.
      a. Curaçoa, &c.

3. Mineral or rock phosphate.
   a. South Carolina.
   b. Navassa.
   c. Apatite, &c.

III. Grades of fineness: The grades of fineness will naturally depend upon what the market affords. We might use, for instance:
1. Coarse.
2. Medium.
3. Fine.

IV. Quantities of phosphoric acid:

Each of the several forms may be used in different "rations," the several rations making a group, as in the nitrogen experiments.

DETAILED PLANS.

For the specific materials to furnish the phosphoric acid in the soluble and precipitated forms, the following are perhaps as well fitted for the purpose as any. Of course others will suggest themselves.

1. Soluble phosphoric acid:
   a. Dissolved bone black with 16 per cent. P_2O_5.
   b. High-grade superphosphate with 32 per cent. P_2O_5.

   Of the above, perhaps (*a*) will serve best to begin with.
2. Precipitated phosphoric acid. This may consist of—
   a. High-grade superphosphate with equal weights of chalk, making a preciptated phosphate with 16 per cent. P_2O_5.
3. Insoluble phosphoric acid. For this, bone, phosphatic guanos, and mineral or rock phosphates will be in order. Bone and South Carolina phosphate are perhaps the most important at present:
   a. Fine bone dust (mesh, 40.) from steamed or raw bone with 25 per cent. P_2O_5.
   b. South Carolina phosphate with 25 per cent. P_2O_5.

QUANTITIES OF PHOSPHORIC ACID.

As already suggested, we may arrange for each of the phosphatic compounds a group of four rations. Below are examples with quantities per acre:

	Ration.	Dissolved bone black.		Ration.	Precipitated superphosphate.
		Pounds.			*Pounds.*
Superphosphate Group.	*a.* One-sixth	100	Precipitated Phosphate Group.	*a.* One-sixth	100
	b. One-third	200		*b.* One-third	200
	c. Two-thirds	400		*c.* Two-thirds	400
	d. Full	600		*d.* Full	600
	Ration.	**South Carolina superphosphates.**		**Ration.**	**Steamed bone.**
		Pounds.			*Pounds.*
South Carolina Superphosphate Group.	*d.* One-sixth	133	Steamed Bone Group.	*a.* One-sixth	67
	b. One-third	267		*b.* One-third	133
	c. Two-thirds	533		*c.* Two-thirds	267
	a. Full	800		*d.* Full	400

The effects of fineness of pulverization may be tested by such groups as these:

	Grade of fineness.	Ground bone.		Grade of fineness.	Phosphate.
		Pounds.			*Pounds.*
FINE, MEDIUM, AND COARSE BONE DUST GROUP	Fine	400	FINE, MEDIUM, AND COARSE S. C. PHOSPHATE GROUP.	Fine	400
	Medium	400		Medium	400
	Coarse	400		Coarse	400

The details of quantities per acre and percentages of the Superphosphate Group, for instance, will be:

	Fertilizing materials.			Ingredients.					
SUPERPHOSPHATE GROUP.	Nitrogen mixture, pounds per acre.	Muriate of potash, pounds per acre.	Superphosphate, pounds per acre.	Nitrogen, pounds per acre.	Potash, pounds per acre.	Phosphoric acid, pounds per acre.	Nitrogen, per cent.	Potash, per cent.	Phosphoric acid, per cent.
A. One-sixth ration	150	133	100	24	67	16	6.3	17.3	4.2
B. One-third ration	150	133	200	24	67	32	5.0	12.9	6.7
C. Two-thirds ration	150	133	400	24	67	64	3.5	9.8	9.4
D. Full ration	150	133	600	24	67	96	2.7	7.6	10.9

That is to say, the Superphosphate Group would thus consist of four mixtures. Each of these mixtures will contain a "basal mixture" with nitrogen and potash each in ½ ration. To this basal mixture the superphosphate is added in successive amounts, from "one-sixth ration" to "full ration," or from 16 to 96 pounds per acre.

SULPHATE OF LIME GROUP.

Since more or less of the effect of the superphosphate may be due to its sulphate of lime, a check trial with plaster as provided in the schedule on page 31 may be advisable.

The explanation of the nitrogen experiment will apply, *mutatis mutandis*, to the phosphoric acid experiment. The idea is to so arrange the materials that each experimenter may select groups or parts of groups at his discretion and thus make up such an experiment as will be most to the purpose in the conditions under which he works.

The following list of materials and groups includes perhaps the most important, and suggests a schedule of experimental fertilizers:

Partial Fertilizers... { Preliminary Group, each by itself, and two by two. } Thus testing the effects of ingredients separately, and capacity of soil to supply them.

Complete Fertilizers. {
- Soluble phosphoric acid Group.
- Precipitated phosphoric acid Group.
- Insoluble phosphoric acid Group. Steamed bone.
- Insoluble phosphoric acid Group. Raw bone.
- Insoluble phosphoric acid Group. S. C. phosphate.
- Sol., Precip., and Insol. Phos. acid Group. S. C. superphosphate.
- Etc., etc.

} Phosphoric acid in one-sixth ration, one-third ration, two-thirds ration, and full ration.

{
- Raw bone Group.
- South Carolina phosphate Group.
- Etc., etc., etc.

} Different grades of fineness.

SCHEDULES FOR EXPERIMENTS.

While experimenters will arrange their experiments at discretion, it has seemed to me desirable to suggest schedules, and, if practicable, to make arrangements to assist them in procuring the materials with the least trouble and expense. I have, therefore, drawn up schedules for three sets of experimental fertilizers, as follows:

The first, "*Nitrogen Set No.* 1," is nearly the same as used by a number of gentlemen last season. Nitrogen is supplied as nitric acid, ammonia, and organic nitrogen, in three groups with three rations, ⅓, ⅔, and full ration, in each. The set requires 18 plots for the fertilizers, which, with two unmanured, would make 20 plots, or, with one-twentieth acre plots, one acre of land, for the experiment. With spaces between the plots a larger area will be needed.

NITROGEN SET NO. 1.

	Materials.	Amounts. Acre set—for one-twentieth acre plots.	Amounts. Two-acre set—for one-tenth acre plots.
		Pounds.	*Pounds.*
Preliminary Group ..	1. Nitrate of soda, one-third ration	7.5	15.0
	2. Superphosphate	20.0	40.0
	3. Muriate of potash	6.7	13.3
	4. Nitrate of soda, one-third ration; Superphosphate	7.5; 20.0	15.0; 40.0
	5. Nitrate of soda, one-third ration; Muriate of potash	7.5; 6.7	15.0; 13.3
	6. Superphosphate, Muriate of potash } Mixed minerals.	20.0; 6.7	40.0; 13.3
Nitrate of soda Group	7. Mixed minerals, as No. 6; Nitrate of soda, one-third ration	26.7; 7.5	53.3; 15.0
	8. Mixed minerals, as No. 6; Nitrate of soda, two-thirds ration	26.7; 15.0	53.3; 30.0
	9. Mixed minerals, as No. 6; Nitrate of soda, full ration	26.7; 22.5	53.3; 45.0
	6*a*. Mixed minerals, as No. 6	26.7	53.3
Sulphate of ammonia Group.	10. Mixed minerals, as No. 6; Sulphate of ammonia, one-third ration	26.7; 5.6	53.3; 11.3
	11. Mixed minerals, as No. 6; Sulphate of ammonia, two-thirds ration	26.7; 11.3	53.3; 22.5
	12. Mixed minerals, as No. 6; Sulphate of ammonia, full ration	26.7; 16.8	53.3; 33.7
	6*b*. Mixed minerals, as No. 6	26.7	53.3
Dried blood Group ..	13. Mixed minerals, as No. 6; Dried blood, one-third ration	26.7; 11.0	53.3; 22.0
	14. Mixed minerals, as No. 6; Dried blood, two-thirds ration	26.7; 22.0	53.3; 44.0
	15. Mixed minerals, as No. 6; Dried blood, full ration	26.7; 33.0	53.3; 66.0
	6*c*. Mixed minerals, as No. 6	26.7	53.3

The following, "*Nitrogen Set No.* 2," is simpler, containing only the preliminary group, and a nitrogen mixture group with five rations, and one extra "mixed minerals." It has the advantage of greater simplicity, and of testing the effects of smaller quantities of nitrogen, but has the disadvantage of not duplicating the nitrogen tests. It can be greatly improved by duplicating the "nitrogen mixture" group, which, with an extra "mixed minerals," will make 18 fertilizers. With one-twentieth acre plots this would require an acre, and make an excellent experiment.

NITROGEN SET NO. 2.

		Materials.	Amounts. Set—for one-twentieth acre plots.	Set—for one-tenth acre plots.
			Pounds.	*Pounds.*
Preliminary Group..	1.	Nitrogen mixture, one-third ration	7.5	15.0
	2.	Superphosphate	20.0	40.0
	3.	Muriate of potash	6.7	13.3
	4.	Nitrogen mixture, one-third ration	7.5	15.0
		Superphosphate	20.0	40.0
	5.	Nitrogen mixture one-third ration	7.5	15.0
		Muriate of potash	6.7	13.3
	6.	Superphosphate	20.0	40.0
		Muriate of potash	6.7	13.3
Nitrogen mixture Group.	7.	Mixed minerals	26.7	53.3
		Nitrogen mixture, one-twelfth ration	1.9	3.8
	8.	Mixed minerals	26.7	53.3
		Nitrogen mixture, one-sixth ration	3.7	7.5
	9.	Mixed minerals	26.7	53.3
		Nitrogen mixture, one-third ration	7.5	15.0
	10.	Mixed minerals	26.7	53.3
		Nitrogen mixture, two-thirds ration	15.0	30.0
	11.	Mixed minerals	26.7	53.3
		Nitrogen mixture, full ration	22.5	45.0
	6*a*.	Mixed minerals	26.7	53.3

The following specifications are intended for use in ordering the fertilizers:

Specifications for nitrogen sets.—Materials to be weighed and mixed with greatest possible care and accuracy, put in bags, and each bag furnished with a label stating number and contents per schedule. *Minimum* percentages as follows: Nitrate of soda, 16 per cent. nitrogen; sulphate of ammonia, 21 per cent. nitrogen; dried blood, 11 per cent. nitrogen; superphosphate (dissolved bone black) 15 per cent. soluble and 16 per cent. total phosphoric acid; muriate of potash, 50 per cent. potash.

PHOSPHORIC ACID SET.

This tests the action of soluble phosphoric acid, in dissolved bone black, precipitated phosphoric acid in a mixture of high grade superphosphate from bone and chalk, and insoluble phosphoric acid in bone from which the larger part of the organic matter has been removed. A sulphate of lime group is added as a test of the effect of the sulphuric acid and lime of the superphosphates. This includes 25 fertilizers, which with two unmanured plots would require 27 plots, or, if each plot is one-twentieth acre, a little over 1½ acres, and more if unmanured strips are left between the rows. The set can be reduced to 21 by omitting the sulphate of lime group, and to 18 by using only three rations in each phosphoric acid group.

PHOSPHORIC ACID SET.

Materials.			Amounts. Regular size for one-twentieth acre plots.	Amounts. Double size for one-tenth acre plots.
			Pounds.	*Pounds.*
Preliminary Group	A.	Nitrogen mixture	7.5	15.0
	B.	Superphosphate	20.0	40.0
	C.	Muriate of potash	6.7	13.3
	D.	Nitrogen mixture	7.5	15.0
		Superphosphate	20.0	40.0
	E.	Muriate of potash	6.7	13.3
		Superphosphate	20.0	40.0
	F.	Nitrogen mixture. } Basal mixture	7.5	15.0
		Muriate of potash } Basal mixture	6.7	13.3
Soluble phosphoric-acid Group.	A.	Basal mixture	14.2	28.3
		Dissolved bone black	5.0	10.0
	B.	Basal mixture	14.2	28.3
		Dissolved bone black	10.0	20.3
	C.	Basal mixture	14.2	28.3
		Dissolved bone black	20.0	40.0
	D.	Basal mixture	14.2	28.3
		Dissolved bone black	30.0	60.0
	Fa.	Basal mixture	14.2	28.3
Precipitated phosphoric-acid Group.	A.	Basal mixture	14.2	28.3
		Precipitated phosphate	5.0	10.0
	B.	Basal mixture	14.2	28.3
		Precipitated phosphate	10.0	20.0
	C.	Basal mixture	14.2	28.3
		Precipitated phosphate	20.0	40.0
	D.	Basal mixture	14.2	28.3
		Precipitated phosphate	30.0	60.0
	Fb.	Basal mixture	14.2	28.3
Steamed bone Group.	A.	Basal mixture	14.2	28.3
		Bone dust	5.0	10.0
	B.	Basal mixture	14.2	28.3
		Bone dust	10.0	20.0
	C.	Basal mixture	14.2	28.3
		Bone dust	20.0	40.0
	D.	Basal mixture	14.2	28.3
		Bone dust	30.0	60.0
	Fc.	Basal mixture	14.2	28.3
Sulphate of lime Group.	A.	Basal mixture	14.2	28.3
		Plaster	3.8	7.5
	B.	Basal mixture	14.2	28.3
		Plaster	7.5	15.0
	C.	Basal mixture	14.2	28.3
		Plaster	11.3	22.5
	Fd.	Basal mixture	14.2	28.3

Besides the above set, groups like the following may be employed:

		Materials.	Amounts. Regular size for one-twentieth acre plots.	Amounts. Double size for one-tenth acre plots.
			Pounds.	*Pounds.*
South Carolina superphosphate Group.	A.	Basal mixture	14.2	28.3
		South Carolina superphosphate	6.7	18.3
	B.	Basal mixture	14.2	28.3
		South Carolina superphosphate	13.3	26.7
	C.	Basal mixture	14.2	28.3
		South Carolina superphosphate	26.7	53.4
	D.	Basal mixture	14.2	28.3
		South Carolina superphosphate	40.0	80.0
South Carolina phosphate Group.	A.	Basal mixture	14.2	28.3
		South Carolina phosphate		
	B.	Basal mixture	14.2	28.3
		South Carolina phosphate		
	C.	Basal mixture	14.2	28.3
		South Carolina phosphate		
	D.	Basal mixture	14.2	28.3
		South Carolina phosphate		
Steamed bone group.	A.	Basal mixture	14.2	28.3
		Steamed bone	5.0	10.0
	B.	Basal mixture	14.2	28.3
		Steamed bone	10.0	20.0
	C.	Basal mixture	14.2	28.2
		Steamed bone	20.0	40.0
	D.	Basal mixture	14.2	28.3
		Steamed bone	30.0	60.0
Fine, medium, and coarse bone Group.	A.	Basal mixture	14.2	28.3
		Ground bone (fine)	20.0	40.0
	B.	Basal mixture	14.2	28.3
		Ground bone (medium)	20.0	40.0
	C.	Basal mixture	14.2	28.3
		Ground bone (coarse)	20.0	40.0
Fine, medium, and coarse South Carolina phosphate Group.	A.	Basal mixture	14.2	28.3
		South Carolina phosphate (fine)	20.0	40.0
	B.	Basal mixture	14.2	28.3
		South Carolina phosphate (medium)	20.0	40.0
	C.	Basal mixture	14.2	28.3
		South Carolina phosphate (coarse)	20.0	40.0

Specifications for fertilizers of phosphoric acid set: Materials to be put up with greatest care in bags, with labels stating contents. Minimum percentages as follows: Nitrogen mixture and muriate of potash as in nitrogen experiment. Superphosphate (dissolved bone black) with 15 per cent. soluble, and 16 per cent. total P_2O_5. Precipitated phosphate to consist of high grade superphosphates 32 per cent. and chalk in equal parts, and to contain 16 per cent. P_2O_5. Other materials to be of good average quality.

CROPS TO BE EXPERIMENTED UPON.

The kind of crop will, of course, be selected by the experimenter. Experiments are needed upon all our ordinary crops, but especially on wheat, barley, rye, oats, corn, sorghum, grass, clover, onions, potatoes, roots, and, in the South, sugar cane and cotton.

The following is a copy of directions for experiments suggested to accompany the above plans:

CO-OPERATIVE EXPERIMENTS WITH FERTILIZERS.

Directions for Special Nitrogen and Phosphoric Acid Experiments.

GENERAL SUGGESTIONS.

1. It is important to have plans complete and clearly in mind, and everything ready before starting. Proper plans at the outset; uniform soil, which should also be "worn-

out" if its permanent capacity for production and the true effects of the fertilizers are to be tested; plots of proper size, shape, and accurately laid out; right application of the fertilizers; good seed; careful measurement of crops; full notes of details; and careful observation of the effects of the fertilizers on succeeding crops, are essential to the best results.

CHOICE OF EXPERIMENTAL FIELD.

2. Uniformity of soil is of the utmost importance. There will be more or less variation in different parts of the same field at best. The unevenness is sometimes so great as to spoil the experiment. The less the variation the more reliable will be the results. Level land should be chosen if practicable, but if it be sloping let the plots run up and down the ascent, so that wash by rains will not transfer the materials from one plot to another.

"WORN-OUT" SOILS FOR THE TESTS.

3. The object is to learn what can be done by the soil with its "natural strength." A store of plant food, either accumulated by natural processes or left over from previous manuring, would obscure the action of the fertilizers, and render the experiments indecisive.

DIMENSIONS OF PLOTS.

4. It is well to make the plots long and narrow, so as to compensate as far as possible for the unevenness of the soil. If the soil is even, small, short plots will do, but generally it will not be even, and long strips are, therefore, safer. To this end let the whole area be as long and narrow as convenient, and the plots run lengthwise through it. If the seed is to be planted in rows the length can be adapted to the distance of the rows apart. If this space is less than two and one-half feet, it will be best to leave an unmanured row between each two strips. In general, an unmanured strip, three feet wide, or wider, should be left between each two plots, so as to prevent the crop of one from being affected by the manure of another. If this is too inconvenient, the next best plan will probably be to cultivate between the rows deep enough to cut the roots and prevent them from feeding on their neighbor's fertilizers.

Strong stakes should be driven firmly into the ground at the boundaries of the plots and not allowed to be knocked over or plowed up.

The following figures will be of service in calculating the dimensions of the experimental plots and field.

To calculate the size of plot of 1-20 acre, find in the left-hand column "Width," the figure for the width decided upon, the opposite figure in the right-hand column will represent the length. Or, given the length in the right-hand column, the opposite figure in the left-hand column will be the width. For 1-10-acre plots, take of course double the given length for same width, or double the given width for same length.

ONE-TWENTIETH ACRE PLOTS, WIDTH AND LENGTH.

Assumed width.	Required length.			Assumed width.	Required length.		
Rods:	*Feet.*	*Rods.*	*Ft.*	Rods:	*Feet.*	*Rods.*	*Ft.*
One-third	396	= 24	00	Two-thirds	198	= 12	00
Two-fifths	330	= 20	00	Three-fourths	176	= 10	11
One-half	264	= 16	00	Four-fifths	165	= 10	00
Three-fifths	220	= 13	5½	One	132	= 8	00
Feet:				Feet:			
6	363	= 22	00	11½	189	= 11	8
6½	335	= 20	5	12	182	= 11	00
7	312	= 18	14	12½	174	= 10	8
7½	291	= 17	10	13	168	= 10	3
8	273	= 16	8	13½	161	= 9	11
8½	257	= 15	9	14	155	= 9	7
9	242	= 14	10	14½	150	= 9	2
9½	230	= 15	15	15	145	= 8	13
10	218	= 13	4	15½	141	= 8	8
10½	208	= 12	9	16	136	= 8	4
11	198	= 12	00	16½	132	= 8	00

For an area of one acre, 160 square rods, 10 x 16 rods will be good dimensions. This will make twenty plots—each ½ rod x 16 rods = 8 sq. rods, = 1-20 acre. Unmanured strips between the plots will, of course, increase the size of the experimental field.

FERTILIZERS WELL DIFFUSED THROUGH SOIL.

5. In general, it is well to apply the fertilizers broadcast. They may, however, be put in the hill or drill, *provided they are well diffused through the soil* To accomplish this, it is well to mix them with several times their bulk of earth, saw-dust, or other diluent, before using. The important points are, that they be:

1st. Applied evenly over the plots where they belong and not allowed to get outside.

2nd. Well distributed through the soil. When the seed is in hills or drills an excellent plan is to spread the fertilizers over a space, say two feet wide, along the row.

UNMANURED PLOTS AND DUPLICATE MANURED PLOTS FOR COMPARISON.

6. Unmanured plots will, of course, be left for tests of capacity of the soil. Both these and the duplicate "mixed minerals" of the nitrogen experiment or "basal mixtures" of the phosphoric acid experiment will test the uniformity of the soil.

REPORTS.

7. Blanks will be forwarded to experimenters for recording and reporting details as to soil, culture, weather, and products. The observations and notes made during the growth of the plants will greatly enhance the value of the reports.

PLAN OF EXPERIMENTAL FIELD.

The plan herewith shows a fitting arrangement for the "Nitrogen Experiment No. 1, 1882," and illustrates how others may advantageously be planned.

NITROGEN EXPERIMENT.

ARRANGEMENT OF EXPERIMENTAL FIELD.

With "Acre set." Each plot 1-20 acre.
Whole field one acre.
With "Two-acre set." Each plot 1-10 acre.
Whole field two acres.
} Or more with unmanured strips between each two plots.

	0	No manure.
Preliminary Group.	1	Nitrate of soda.
	2	Superphosphate.
	3	Muriate of potash.
	4	Nitrate of soda and superphosphate.
	5	Nitrate of soda and muriate of potash.
	6	Superphosphate and muriate of patash. "Mixed minerals."
Nitric Acid Group.	7	Mixed minerals plus nitrate of soda. One-third ration.
	8	Mixed minerals plus nitrate of soda. Two-thirds ration.
	9	Mixed minerals plus nitrate of soda. Full ration.
	6*a*	Mixed minerals. Duplicate of No. 6.
Ammonia Group.	10	Mixed minerals plus sulphate of ammonia. One-third ration.
	11	Mixed minerals plus sulphate of ammonia. Two-thirds ration.
	12	Mixed minerals plus sulphate of ammonia. Full ration.
	6*b*	Mixed minerals. Duplicate of No. 6.
Organic Nitrogen Group.	13	Mixed minerals plus dried blood. One-third ration.
	14	Mixed minerals plus dried blood. Two-thirds ration.
	15	Mixed minerals plus dried blood. Full ration.
	6*c*	Mixed minerals. Duplicate of No. 6.
	00	No manure.

APPENDIX.

EXPLANATION OF TABLES.

It has seemed to me that the best way to dispose of the very large mass of materia which the reports of the experiments make up, will be to arrange it as far as possible in tabular form; and to put the larger and more detailed tables by themselves, as is attempted here.

TABLE I.—This table gives the results of experiments with corn described above. As was explained, the details regarding soil, culture, weather, &c., as reported by the experimenters, are given beyond.

TABLE II gives results of experiments with potatoes on the plan of those with corn of Table I.

TABLE III gives similar results of experiments with corn, cotton, clover, and potatoes. It will be noticed that these experiments were all made in the year 1881, upon a schedule slightly different from that of Tables I and II. The differences in these schedules have all been explained above.

TABLES IV to IX.—These tables include what we have called the "general experiments" (that is, those that were made primarily as soil tests). As space scarcely permits the printing of all the details as to the soil, culture, weather, &c., which were given by the experimenters in their reports, some principal data have been tabulated along with the figures for produce. Table IV gives experiments with corn in 1878; Table V, those with potatoes in 1878; Tables VI and VII include the experiments of 1879; Tables VIII and IX those of 1880.

It will be noted that no tables are given for the general experiments of 1881. I have felt that those are sufficient for their purpose, and have taken no pains to see to a report of the general experiments since 1880. As I look over the matter now, however. I am by no means certain that it would not have been eminently desirable, had my other engagements allowed, to collate and put in print the results obtained in 1881. Still, it has been my idea from the outset, that the experiments should be made gradually to assume a more and more scientific character; and in accordance with that, have, in the latter season, paid less heed to the general and more to the special experiments.

TABLE X.—This table is intended to show (1) the regularity and irregularity of the action of the different materials; (2) the specific effects of the substances furnishing nitrogen, phosphoric acid, potash, and plaster, in the different plots of each experiment. Full explanations may be found in the portion of the article which treats of this subject.

TABLE XI gives the figures selected from Table X, and includes experiments whose results were so free from the impairments due to climate, season, culture, and especial irregularities of soil, as to make them of a special value in illustrating the specific effects of the different materials, and thus throwing light upon the feeding capacities of plants.

TABLE XII gives partial averages of results of the experiments of 1878 to 1881, that is, they include several plots of the general experiments, and the similar plots of the special ones.

TABLE XIII recapitulates the results of the special nitrogen experiments.

Following Table XIII is a condensed statement of the details of the special nitrogen experiments as regards soil, culture, cropping, &c.

TABLE I.—SPECIAL

Effects of nitroge

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Potash and [illegible]rn, nitrogen in one-th

ubsoil, heavy, moist, unde
worn-out meadow. *Weathe*
were in continuation of th
1878. *Soil*.—Heavy loam,
oil.—Clay loam, compact s
nother portion of the same
worn-out meadow, pasture
rather dry—worn-out mea
in 1879, after rye in 1878, a

1 acre =
1 bushel =
1 pound (avoirdupois) =
1 bushel per acre =
1 pound per acre =

No. of plot.	Classification.	B. '78. Total.	B. '78. Stalks.	C. '79. Total.
		Bu.	*Lbs.*	*Bu.*
0		17.7	.....	7.7
1	GROUP I. Valuable ingredients, singly.	15.1	947	7.4
2		39.9	1,640	36.5
3		19.1	1,210	7.7
4	GROUP II. Valuable ingredients, two by two.	41.9	1,660	41.4
5		21.1	1,300	7.1
6		43.1	1,920	42.0
7	GROUP III. Nitrogen (as nitrate of soda) in different proportions.	51.7	2,200	45.7
8		47.3	2,290	46.8
9		47.3	2,280	42.2
6a				
00				8.5
10	GROUP IV. Nitrogen in mixture, in different proportions.	50.0	2,330	44.0
11		50.7	2,400	44.5
12		56.4	2,860	39.1
6b				
13	GROUP V. Nitrogen, ⅓ ration, in different combinations.	58.1	2,490	40.2
14		55.0	3,230	40.7
15		55.3	2,390	38.5
16				36.5
17		49.8 (7)	2,350	
000				

(1) The "nitrogen mixture[illegible]t., and supplied not far from
phosphoric acid and 75 lbs. of "[illegible] in computing averages. (6). S

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C. 79

s.	Total.
	Bu.
..	7.7
7	7.4
0	36.5
0	7.7
0	41.4
0	7.1
0	42.0
0	45.7
0	46.8
0	42.2
..	8.5
0	44.0
0	44.5
	39.1
	40.2
	40.7
	38.5
.	36.5

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TABLE II.—SPECIAL NITROGEN EXPERIMENTS.

Effects of nitrogenous fertilizers upon potatoes and oats.

Potash supplied at rate of about 75 lbs., phosphoric acid 48 lbs., and nitrogen in "¼ ration" 24 lbs., in "½ ration" 48 lbs., and "full ration" 72 lbs. per acre.

C. 1879 1880 and 1881 W. I. BARTHOLEMEW, Putnam, Conn. *Soil.*—Hill land, dark loam, compact subsoil, worn-out meadow Experiment repeated with the same fertilizers and crops on the same plots year after year. *Weather.*—1879, cold, wet, unfavorable; 1880, favorable; 1881, very unfavorable.
I. CHARLES FAIRCHILD, Middletown, Conn *Soil.*—Upland, sandy loam, sandy subsoil, rather dry. *Previous crop.*—Corn. *Weather.*—Favorable.
(Concerning further details as to soil, culture, weather, etc., see page ——.)

No. of plot.	FERTILIZERS. Classification.	Kinds and amounts per acre.	Nitrogen.	POTATOES—YIELD PER ACRE IN BUSHELS. C. '79. Good.	C. '79. Poor.	C. '79. Total.	C. '80. Good.	C. '80. Poor.	C. '80. Total.	C. '81. Good.	C. '81. Poor.	C. '81. Total.	L. '81. Total.	Total average.	OATS—(STRAW IN POUNDS). Grain.	Straw.
				Bu.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lbs.*
0		0. No manure		30	16	46	50	28	78	16	28	44	28	49	26.9	1,180
1	GROUP I.	1. Nitrogen mixture (1)	¼ ration	22	20	42	80	10	90	26	22	48	42	55	38.1	1,820
2		2. Superphosphate, 300 lbs. (2)		46	32	78	80	32	112	34	24	58	56	76	33.3	1,900
3		3. Muriate of potash, 150 lbs. (3)		24	22	46	100	16	116	24	26	50	60	68	31.3	1,720
4	GROUP II. Valuable ingredients, two by two.	4. Nitrate of soda, 150 lbs. + Superphosphate, 300 lbs	¼ ration	78	36	114	90	22	112	32	26	58	94.7	94.7	51.9	2,660
5		5. Nitrate of soda, 150 lbs. + Mur of potash, 150 lbs	½ ration	32	20	52	86	26	112	26	26	52	68	71	42.5	2,160
6		6. Superphos 300 lbs. + Mur pot 150 lbs. + Mixed min'l fertilizers (4)		81	34	115	62	32	114	54	20	74	90.7	98.4	33.3	2,290
7	GROUP III. Nitrogen (as nitrate of soda) in different proportions.	7. Mixed min. fertilizers (as No. 6) + Nitrate of soda 150 lbs	¼ ration	84	46	130	124	28	152	76	24	100	124.7	126.7	54.4	3,500
8		8. Mixed mineral fertilizers + Nitrate of soda, 300 lbs	½ ration	106	40	146	166	36	202	86	30	96	138.7	146.2	59.4	3,880
9		9. Mixed mineral fertilizers + Nitrate of soda, 450 lbs	Full ration	88	42	130	116	28	144	64	26	90	120	121	59.4	4,380
6a		6a Mixed min. fertilizers (as No. 6)		...									94	(94)	30.3	1,760

00		00. No manure		82	24	56	62	....	62	36	26	90	96	117	35.0	1,760
10	Group IV. Nitrogen in mixture in different proportions.	10. Mixed mineral fertilizers, Nitrogen mixture,[2] 150 lbs	½ ration	134	32	166	100	16	116	84	30	114	122.7	129.7	51.9	3,140
11		11. Mixed mineral fertilizers, Nitrogen mixture, 300 lbs	⅔ ration	106	36	142	122	20	142	82	26	108	144.7	134.2	55.6	3,380
12		12. Mixed mineral fertilizers, Nitrogen mixture, 450 lbs	Full ration	116	30	146	108	30	138	92	22	114	144.7	135.7	59.4	3,780
6b		6b. Mixed min. fertilizers (as No. 6)											110	(110)	33.8	1,760
13	Group V. Nitrogen, ⅔ ration, in different combinations.	13. Mixed mineral fertilizers, Sulphate of ammonia, 225 lbs	⅔ ration	112	44	156	114	26	140	78	24	102	135.3	138.3	61.9	3,700
14		14. Mixed mineral fertilizers, Dried blood, 450 lbs	⅔ ration	110	48	158	132	26	158	86	24	110	134.7	140.2	53.8	3,080
15		15. Peru. guano, "Standard," 550 lbs., Muriate of potash, 150 lbs	⅔ ration	92	40	132	126	28	154	76	26	102	133.3	130.3	54.4	2,980
16		16. Mixed min. fertilizers (as No. 6)		86	38	124	126	32	158	62	28	90	96	117	35.0	1,760
000		000. No manure											29.3	(29.3)	26.3	1,120

TABLE III.—SPECIAL NITROGEN EXPERIMENTS.

Effects of nitrogenous fertilizers upon corn, cotton, clover, and potatoes.

Potash supplied at rate of about 75 lbs. per acre; phosphoric acid, 48 lbs.; and nitrogen in "¼ ration" 24 lbs., in "½ ration" 48 lbs., and "full ration" 72 lbs. per acre.

L. 1881. W. C. NEWTON, Barham, Conn. *Soil.*—Old meadow, hill land, dark loam, moist subsoil. *Weather.*—Unfavorable.
M. 1881. Prof. C. L. INGLE, Purdue University, Lafayette, Ind. *Soil.*—Upland, level, black, similar to prairie, gravel subsoil. *Weather.*—Very dry and unfavorable.
N. 1881. C. E. THORNE, Ohio State University, Columbus, Ohio. *Soil.*—Clayey loam, subsoil similar to surface soil, retentive. *Weather.*—Very dry.
O. 1881. J. W. PIERCE, West Millbury, Mass. *Soil.*—Worn-out grass land, clay loam, gravelly subsoil. *Weather.*—Cold and unfavorable.
P. 1881. EDWARD HICKS, Old Westbury, N. Y. *Soil.*—Level, sandy loam, yellow loam subsoil. *Weather.*—Dry and unfavorable.
Q. 1881. Prof. SAMUEL JOHNSON, Michigan Agricultural College, Lansing, Mich. *Soil.*—Level, upland, sandy loam, gravelly subsoil. *Weather.*—Dry, cold, and unfavorable.
R. 1881. Prof. W. C. STUBBS, Alabama Agricultural and Mechanical College, Auburn, Ala. *Soil.*—Worn-out pasture, sandy, light, well drained, reddish yellow clay, subsoil. *Weather.*—Dry and unfavorable.
S. 1881. J. M. MANNING, Taunton, Mass. *Soil.*—Upland, sandy loam, loose, yellow sand subsoil. *Weather.*—Unfavorable.
(Concerning further details as to soil, culture, weather, &c., see page —.)

No. of plot.	Classification.	Fertilizers. Kinds and amounts per acre.	Nitrogen.	Yield per acre. Corn. M. '81. Total.	M. '81. Stalks.	N. '81. Total.	N. '81. Stalks.	O. '81. Total.	O. '81. Stalks.	P. '81. Good.	P. '81. Poor.	P. '81. Total.	Q. '81. Good.	Q. '81. Poor.	Q. '81. Total.	L. '81. Total.	Total average corn.	Cotton. R. '81. Total.	Clover. S. '81. Total.	Potatoes. M. '81. Total.
				Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Lbs.	Lbs.	Bu.
0		0. Nothing		38.2	1,760	40.0	2,040	10.3	380	13.0	3.3	16.3	37.4	7.3	44.7	12.52	27.0	587	480	12.8
1		1. Nitrate of soda	¼ ration	35.9	1,920	44.3	2,420	11.7	1,080	23.2	2.8	26.0	45.6	7.5	53.1	22.5	32.2	865	700	42.7
2	Preliminary Group.	2. Superphosphate		36.4	1,920	48.6	2,480	16.0	1,360	18.8	4.0	22.8	41.8	6.3	51.2	13.8	31.4	1,162	1,200	17.1
3		3. Muriate of potash		34.5	1,840	48.6	2,600	17.7	1,640	30.0	4.5	34.5	47.0	5.1	52.0	15.0	38.7	564	940	9.1

4	Valuable ingredients, singly and two by two.	4.	Nitrate of soda Superphospate	½ ration	33.6	1,760	50.3	2,720	14.3	1,140	20.2	4.3	24.3	54.8	6.9	61.6	23.8	34.6	1,599	1,080	10.7
5		5.	Nitrate of soda Muriate of potash		34.5	1,840	44.9	2,200	23.0	1,960	24.2	5.3	29.5	39.6	4.0	43.6	28.8	33.2	932	560	5.9
6		6.	Superphosphate. } Mixed Muriate potash.. } minerals		34.5	1,888	52.0	2,860	34.6	2,220	25.4	2.8	28.2	55.1	3.8	59.0	13.8	37.0	1,219	1,140	13.9
7	Nitric Acid Group.	7.	Mixed minerals, as No. 6... Nitrate of soda	½ ration	37.3	1,840	49.1	2,920	34.0	2,200	23.2	5.5	28.7	52.9	5.9	58.8	23.3	38.5	1,541	1,200	38.6
8		8.	Mixed minerals Nitrate of soda	⅔ ration	32.5	1,760	45.7	2,440	35.7	2,440	29.8	4.0	33.8	51.3	4.3	55.6	41.7	40.8	1,404	1,460	79.4
9		9.	Mixed minerals Nitrate of soda	Full ration.	33.1	1,920	47.4	3,080	41.4	2,660	27.0	4.5	31.5	44.1	5.0	49.1	56.7	43.2	1,242	1,480	85.9
6a		6a.	Mixed minerals, as No. 6		33.4	2,000	46.0	2,760	37.7	2,400	24.8	5.2	30.0	52.3	4.4	56 7	16.3	36.7	3,115	1,660	124.3
10	Ammonia Group.	10.	Mixed minerals Sulph ammonia	½ ration	36.1	2,080	41.7	2,640	39.4	2,720	23.0	4.8	27.8	52.0	8.8	55.7	28.5	38.2	1,116	1,880	130.7
11		11.	Mixed minerals Sulph. ammonia	⅔ ration	38.4	2,160	42.3	2,700	40.3	2,720	26.6	4.2	30.8	55.0	3.9	58.9	42.5	42.2	1,265	2,000	127.4
12		12.	Mixed minerals Sulph. ammonia	Full ration.	34.0	2,160	43.4	2,600	39.4	2,440	27.0	5.5	32.5	46.4	4.0	50.4	48.3	41.3	1,162	2,400	89.6
6b		6b.	Mixed minerals		35.7	2,240	48.3	2,740	28.6	1,980	24.0	5.0	29.0	45.9	5.2	51.0	.....	.....	.....	1,440	55.4
13	Organic Nitrogen Group.	13.	Mixed minerals Dried blood	½ ration	34.0	2,080	41.1	2,360	35.4	2,200	33.0	4.6	37.6	44.2	5.2	49.4	28.8	37.7	1,357	1,620	37.3
14		14.	Mixed minerals Dried blood	⅔ ration	34.5	2,160	41.4	2,580	37.0	2,120	32.7	3.6	36.3	47.6	4.0	51.6	33.8	40.8	1,300	1,940	41.6
15		15.	Mixed minerals Dried blood	Full ration.	33.4	2,320	39.4	2,420	39.0	2,480	32.0	3.2	35.2	58.2	3.2	61.4	40.6	41.5	1,127	2,420	38.4
6c		6c.	Mixed minerals, as No. 6		33.4	2,240	40.9	2,720	....	.....	37.2	2.5	39.7	51.9	5.3	57.1	20.6	31.9	.....	1,200	40.5
00		00.	No manure		31.0	1,685	35.4	2,320	....	....	13.5	3.0	16.5	25.6	6.1	31.7	13.8	21.4	449	800	11.7

TABLE IV.—GENERAL EXPERIMENTS WITH CORN, 1878.

Yields of shelled corn per acre with different fertilizers.

Number of experiment.	0		I.		II.		III.		IV.		XIII.		V.		VI.		VII.				00	
	No manure.		Nitrate of soda, 200 pounds.		Dissolved bone-black, 300 pounds.		Muriate of potash, 200 pounds.		Nitrate of soda, 150 pounds; dissolved bone-black, 300 pounds.		Nitrate of soda, 150 pounds; muriate of potash, 200 pounds.		Dissolved bone-black, 300 pounds; muriate of potash, 200 pounds.		Nitrate of soda, 150 pounds; dissolved bone-black, 300 pounds; muriate of potash, 200 pounds.		Plaster, 200 pounds.		Farm manure.		No manure.	
Cost per acre.			$7.50		$5.25		$4.50		$10.88		$10.13		$9.75		$15.38		$0.80		Variable.			
	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn	Stalks.	Corn.	Stalks.
	Bush.	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*	*Bush.*	*Lbs.*
1	[ ]		6.9		6.5		6.5		8.2		8.7		8.2		10.0		5.0					
2	7.0	2,250	17.5	3,600	10.3	2,800	9.2	2,400	16.5	3,550	15.0	4,050	18.6	3,840	13.5	2,900	14.4	3,000	48.6	5,500		
3	6.4		3.2		23.0		5.8		25.6				22.2		27.4		10.6		10.4		6.6	
4	11.0	1,248	18.0	1,408	11.0	1,184	42.0	3,072	16.0	1,344			48.0	3,744	56.0	2,849	9.0	1,050	50.0	2,944	8.0	1,050
5	5.5	190	7.5	121	10.7	154	7.8	116	18.4	225			14.5	212	18.5	225	9.4	138				
6			6.2		20.0		12.5		32.5				25.0		30.0		17.5				7.5	
7	10.0	520	9.0	570	17.5	790	7.5	610	22.5	990			16.3	830	20.0	1,310	7.0	350	20.0	770	7.5	430
8	7.5		5.6		20 7		7.6		28.8				23.8		27.5		7.5		32.5			
9	5.0		11.0		8.5		19.5		17.0		28.0		26.0		31.0		15.0		23.5			
10	27.5		35.0		35.0		32.5		35.0		32.5		35.0		32.5		27.5		40.0		31.9	1,680
11	28.7	1,610	35.6	1,950	37.5	2,000	35.6	2.300	38.7	2,170			41.9	2,340	51.2	2,870	32.5	1,280	32.5			
12	26.3		35.1		49.5		35.1		67.4				67.4		86.1		55.6		48.1		26.3	
13	27.5	1,550	51.9	2,300	40.0	2,000	49.1	2,200	47.1	2,350	52.4	2,500	47.4	2,220	53.7	2,450	40.0	1,800	52.6	2,340		
14	20.2		40.5		57.2		30.0		67.9				71.0		70.5		23.0		60.0			
15	20.5		43.7		43.7		39.9		46.3		26.0		33.4		41.1		33.0		29.6			
16	24.0		18.5		30.5		20.5		32.0				32.0		31.0		26.0		36.5			
17	35.2		41.0		34.0		45.2		42.3				44.1		51.0		32.0		39.5		32.0	
18	30.5		37.2		36.6		35.0		39.3				42.7		42.7		31.0		47.5			
19	33.0		32.0		31.0		39.3		34.4		30.0		39.6		40.0		27.0		45.0			
20	32.8	2,700	41.8	3,600	32.8	3,600	45.3	4,050	48.5	4.500			64.8	5,850	72.3	8,550	39.0					
21	48.7		58.3		62.6		70.2		68.5		49.9		59.2		70.3		42.6		45.2		41.5	

22	47.6		53.9		50.0		53.4		63.8				62.0		61.0		58.6		65.6		52.5			
23	64.9		69.5		64.7		64.3		65.0		69.1		69.3		80.6		65.7		78.7					
24	49.2		60.0		54.0		37.8		54.3				57.3		76.0		48.3		66.8		41.3			
Average(1).	24.6		30.4		33.5		33.3		39.1		39.6		42.9		48.6		28.9		45.9		24.4			

(1) Including also experiments A, B, and C of Table I.

Kinds and amount of farm manures. *Experiment* 3, hen manure; 4, yard manure, 9 cords per acre; 7, manure 20 loads; 8, stable manure, 6½ cords; 9, manure, 600 bushels; 10, manure, 18 loads; 11, hen manure 15 bushels 12 yard manure, 20 loads. 13, yard manure, 30 loads, 14, yard manure, 18 cords; 15, manure, 20 loads; 16, hen manure, a handfull in each hill, 17, yard manure, 10 loads, 18, hog manure 7½ cords, 19, yard manure; 21, stable manure, 8 cords; 22, yard manure, 40 loads; 23, stable manure, 9 cords.

Yields with other fertilizers, experiment 8.—Ashes 40 bushels, 5.6; 9, ashes, 25 bushels, 35.0, 11, lime, 31.9; 12, leached ashes, 100 bushels, 45; 17, lime, 30 bushels, 34; 20, unleached ashes, 40 bushels, 44.

Number.	Experimenters.	Surface soil. Kind.	Texture.	Moisture.	Subsoil.	Previous cropping.	Weather.			Fertilizers, how applied.
1	Emmor K Haight, Freehold, N J	Clay	Compact	Medium	Compact	Hay	Warm	Moist	Favorable	Broadcast.
2	Buel Lavdon South Hero, Vt	Clay loam	Loose	do	do	Oats	do	Wet	do	Do.
3	G Gilbert Childs, Swopes Depot, Va	do	Compact	Dry	Red clay	Pasture	do	do	do	Do.
4	J H Stiles Morris Plains N J	Gravel	Loose	Medium	Loose	Corn	Cool	do	do	Do.
5	J J Deaving Covington, Ga	Red Clay	do	do	Sandy	Pasture		do	do	Drilled.
6	David B Wertz, Johnstown, Pa	Yellow clay	do	Dry	Clay	Rye	Cool	do	Unfavorable	
7	W C Holman Graham N C	Sandy loam	do	do	Red clay	Corn	do	Dry	Favorable	Hill.
8	Nathan B. Lewis, Pine Hill R I	Gravel	Light	do	Gravel	Rye	do	Moist	do	Broadcast.
9	Z Johnson, Irasburgh, Vt	Sandy	do	Medium	Loose	Hay	Warm	do	do	Do.
10	Ed F Smith, Tunbridge, Vt	Loam	Compact	Wet	Clay	Corn	do	Dry	do	Do.
11	L W. Stone & Son Waverly, Pa	Clay loam	Loose	Dry	Compact	Hay	do	Moist	do	Do.
12	Halsey P Clarke Wyoming R I	Loam			Gravel	do				Do.
13	Seth H Rising, West Rupert, Vt	Gravel	Loose	Dry	do	Corn	Cool	Moist	Unfavorable	Do.
14	C Miller & Son, Pomfert Vt	Loam	Light	Medium	Sand and clay	Hay	do	do	Favorable	Do.
15	Charles P Gale, Plainfield Vt	Sandy loam	do	Dry	Yellow loam	do	Warm	Dry	do	Do.
16	Jonathan Dunham Etna, N Y	Gravelly loam	Loose	do	Stony clay	do	do	Moist	do	Hill
17	A B Clarke Minton, N Y	Loam	do	do	Compact	do	do	do	do	Broadcast
18	M W Ladd Woodstock, Vt	Sandy loam	do	do	Loose	do	do	do	do	Do.
19	H Bradley Brattleboro, Vt	do	Light	do	Sandy	Pasture				Do.
20	William F Segar Wyoming, Vt	do	Loose	Medium	Clay	Hay	Warm	Moist	Favorable	Do.
21	James K Toby Calais Vt	Loam	do	Dry	Loam	Potatoes	Cool	Dry	do	Do.
22	Cicero Blake, Kent Ohio	Clay loam	Light	do	Clay	Hay	Warm	do	Unfavorable	Do.
23	Ora Paul Woodstock, Vt	Loam	do	do	do	do	do	Moist	Favorable	Do.
24	Edward Hicks, Old Westby, N Y	Sandy loam	Loose	do	Gravelly loam	Fodder corn	do	do	do	Hill.

TABLE V.—GENERAL EXPERIMENTS WITH POTATOES, TURNIPS, AND OTHER CROPS IN 1878.

Yields per acre with different fertilizers.

Number of experiment.	Number of fertilizer.	0.	A.	B.	C.	D.	E.	F.	G.	H.		00.
	Fertilizers per acre.	No manure.	Nitrate of soda, 200 lbs.	Dissolved bone-black, 300 lbs.	Muriate of potash, 200 lbs.	Nitrate of soda, 150 lbs.; dissolved bone black, 300 lbs.	Nitrate of soda, 150 lbs.; muriate of potash, 200 lbs.	Dissolved bone-black, 300 lbs.; muriate of potash, 200 lbs.	Nitrate of soda, 150 lbs.; dissolved bone-black, 300 lbs.; muriate of potash, 200 lbs.	Plaster, 200 lbs.	Farm manures.	No manure.
	Cost per acre		$7.50	$5.25	$4.50	$10.88	$10.13	$9.75	$15.38	$0.80	Variable.	
25	Potatoes, bu. per acre	134.0	127.0	127.0	136.0	154.0	122.0	115.0	138.0	132.0	129.0	141.0
26		31.2	30.8	28.4	69.0	37.2	.....	76.4	75.6	31.6	74.8	.....
27		130.0	162.0	200.0	125.0	210.0	.....	220.0	250.0	150.0	.....	.....
28		120.0	102.0	105.0	140.0	150.0	.....	162.0	185.0	100.0	115.0	90.0
29		60.0	76.6	100.0	93.3	106.6	.....	150.0	170.0	93.3	146.0	60.0
30		133.0	13.9	138.0	160.0	149.0	157.0	165.0	200.0	.....	.....	.....
31		141.0	133.0	165.0	209.0	206.0	.....	247.5	270.4	158.0	215.4	.....
32		121.0	117.0	168.0	214.0	176.0	.....	145.0	167.0	123.0	170.0	.....
33		30.0	40.0	80.0	20.0	100.0	60.0	100.0	140.0	60.0	80.0	35.0
	Average	100.0	103.0	123.4	129.6	143.2	106.0	153.4	177.3	106.0	132.9	81.5
34	Sweet potatoes, bu. per acre	68.0	91.0	77.0	110.0	93.0	.....	166.0	177.0	60.0	.....	.....
35		.....	120.0	130.0	140.0	120.0	.....	140.0	170.0	.....	.....	.....
36		26.5	159.0	79.0	189.0	92.5	.....	92.5	212.0	.....	.....	53.0
37		73.0	141.0	73.0	194.0	145.0	194.0	218.0	290.0	.....	290.0	73.0
38	Turnips, do	225.0	285.0	315.0	240.0	428.0	203.0	413.0	518.0	263.0	300.0	.....
39		516.0	565.0	615.0	583.0	593.0	661.0	656.0	785.0	673.0	580.0	505.0
40	Sugar beets, do	787.3	1,013.3	1,174.0	851.3	1,116.0	988.3	1,090.6	1,118.6	960.6	.....	803.3
41	Cotton, lbs. per acre	104.5	38.5	242.0	66.0	599.5	.....	457.0	693.0	44.0	.....	.....
42	Cow peas, bu. per acre	8,0	4.0	5.0	6.0	6.0	.....	8.0	10.0	4.0	.....	.....

Kinds and amounts of farm manure.—*Experiment* 25, stable manure, 8 cords; 28, yard manure, 30 loads; 29, stable manure, 6½ cords; 31, stable manure, 35 loads; 32, stable manure, 20 loads; 39, stable manure, 8 cords.

Yields with other fertilizers.—*Experiment* 29, lime, 500 pounds = 63.3; 36, ashes, 40 bushels = 212.

Number.	Experimenters.	Surface soil.			Subsoil.	Previous cropping.	Weather.			Fertilizers, how applied.
		Kind.	Texture.	Moisture.						
25	James K. Toby, Calais, Vt	Loam	Loose							
26	T. H. Stiles, Morris Plains, N. J	Clay loam	do	Medium	Hard-pan		Cool	Wet	Favorable	Broadcast.
27	W. S. Bartholomew, Putnam, Conn	Loam	Compact	do	Compact	Corn and beans			do	
28	R. P. Wolcott, Holland Patent, N. Y	do	Light	Dry	Clay loam	Fodder corn	Warm	Moist	do	Broadcast.
29	S. W. Crocker, Saint Albans, Me	Clayey	do	Medium	Hard-pan	Grass	Cool	Wet	Unfavorable	Hill.
30	J. R. Kinerson, Peacham, Vt	Sandy loam	Loose	Dry	Sandy	Hay	Warm	Moist	Favorable	Broadcast.
31	Moody P. Marshall, Lancaster, N. H	Stony land.	Light	Medium		Oats	Cool	do	do	Drill.
32	Moody P. Marshall, Lancaster, N. H	do	do	do	Sandy	do	do	do	do	Do.
33	Hiram A. Cutting, Lunenburgh, Vt	Loam	do	Dry	Hard gravel	Hay	do	Wet	Unfavorable	
34	A. P. Arnold, Vineland, N. J	Sandy loam	Loose	do	Sandy	Corn	do	do	do	Drill.
35	A. P. Arnold, Vineland, N. J	do	do	do	do	do	do	do	do	Do.
36	M. Chesboro, Mandarin, Fla	Fine sand	Compact	Medium	Yellow sand	Sweet potatoes				
37	Charles Parry, Cinnaminson, N. J	Sandy	Light	Dry	Sand and gravel	Asparagus	Warm	Moist	Favorable	Row.
38	Prof. J. Farrington, Orono, Me	Heavy clay	Compact	Medium		Meadow				Broadcast.
39	James K. Toby, Calais, Vt	Loam	Loose	Dry	Compact	Potatoes	Cool	Dry	Favorable	Do.
40	Henry Lane, Cornwall, Vt	Clay loam			Slate-rock	Onions				Do.
41	J. J. Dearing, Covington, Ga	Red clay	Compact	Dry	Red clay	Fallow	Warm	Moist	Favorable	Drill.
42	Willard R Hall, Albion, Fla	Sandy	Light	do	Yellow sand		do	do	do	Do.

TABLE VI.—GENERAL EXPERIMENTS WITH CORN, 1879.

Yields per acre with different fertilizers.

Number of experiment.	0. No manure.		A. Nitrate of soda, 200 lbs.*		B. Dissolved bone-black, 300 lbs.		C. Muriate of potash, 200 lbs.†		D. Nitrate of soda, 150 lbs.; dissolved bone-black, 300 lbs.		E. Nitrate of soda, 150 lbs.; muriate of potash, 200 lbs.†		F. Dissolved bone-black, 300 lbs.; muriate of potash, 200 lbs.		G. Nitrate of soda, 150 lbs.; dissolved bone-black, 300 lbs.; muriate of potash, 200 lbs.*		H. Plaster, 200 lbs.		Farm manures.		OO. No manure.	
Cost per acre.			$7.50.		$5.25.		$4 50.		$10.88.		$10.13.		$9.75.		$15.38.		$0.80.		Variable.			
	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.
	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu	Lbs.	Bu.	Lbs.	Bu.	Lbs.	Bu.	Lbs.
1	18.5	.....	20.3	.....	20.3	.....	17.3	.....	19.2	.....	12.9	.....	17.6	.....	20.1	.....	13.0	.....	.....	.....	.....	.....
C	7.7	.....	7.4	.....	36.5	.....	7.7	.....	41.4	.....	7.1	.....	42.0	.....	45.7	.....	.....	.....	36.0	.....	8.5	.....
3	3.3	730	2.7	1,000	12.0	1,880	6.7	1,980	12.0	2,760	5.5	1,620	16.7	3,200	13.7	3,300	3.5	920	39.7	.....	.....	.....
4	19.7	1,800	24.2	1,600	22.3	1,800	11.0	1,200	31.3	1,650	14.0	1,500	27.2	2,250	33.4	2,250	25.8	2,250	18.0	2,100	.....	.....
5	[31.7]	2,360	37.6	2,360	14.6	2,260	6.9	1,880	29.8	3,660	18.4	2,300	10.1	2,460	18.8	2,740	3.7	1,460	.....	.....	.....	.....
6	8.0	1,690	14.7	2,110	23.3	2,890	29.4	3,410	38.7	4,000	38.2	3,800	46.2	4,120	80.2	4,450	10.6	2,200	90.5	4,500	.....	.....
7	5.7	.....	6.8	.....	16.6	.....	10.4	.....	17.7	.....	10.5	.....	21.7	.....	26.6	.....	19.2	.....	32.5	.....	11.6	.....
8	11.3	1,215	11.2	1,276	16.6	1,316	11.0	1,519	18.9	1,413	10.0	1,137	13.3	1,519	15.9	1,661	4.5	1,013	23.9	1,620	.....	.....
9	12.5	.....	37.5	.....	41.2	.....	25.0	.....	22.5	.....	38.0	.....	45.0	.....	45.0	.....	37.4	.....	.....	.....	.....	.....
F	8.3	.....	6.8	.....	7.0	.....	41.3	.....	20.5	.....	39.3	.....	50.3	.....	40.7	.....	.....	.....	46.5	.....	7.1	.....
11	23.9	2,200	16.0	4,000	26.2	3,200	11.0	3,250	44.2	3,200	14.3	3,500	21.4	3,600	37.5	4,360	19.0	1,700	14.8	1,680	.....	.....
12	20.3	.....	22.3	.....	20.0	.....	24.6	.....	37.0	.....	44.3	.....	24.6	.....	19.4	.....	14.0	.....	.....	.....	8.3	.....
13	21.9	.....	27.5	.....	33.7	.....	23.7	.....	30.0	.....	28.7	.....	31.2	.....	38.7	.....	34.7	.....	15.0	.....	.....	.....
14	22.7	1,760	13.3	2,560	49.4	2,880	45.7	3,200	54.5	3,360	42.1	3,360	56.1	3,680	65.0	5,600	.....	.....	58.5	5,120	.....	.....
15	25.4	1,440	22.0	1,680	28.6	1,730	37.1	2,240	32.3	2,200	47.1	3,360	33.4	2,640	57.5	4,480	38.0	2,820	55.5	3,920	.....	.....
16	32.5	.....	47.5	.....	40.0	.....	55.0	.....	50.0	.....	41.2	.....	42.5	.....	41.2	.....	30.0	.....	42.5	.....	32.5	.....
17	38.0	5,920	44.0	6,560	80.0	9,120	73.0	7,420	70.0	7,840	50.0	8,640	64.0	8,000	64.0	8,480	44.0	6,560	.....	.....	44.0	7,120
18	34.0	.....	24.3	.....	45.7	.....	31.6	.....	45.6	.....	24.4	.....	48.8	.....	35.7	.....	46.2	.....	.....	.....	.....	.....
19	30.0	.....	35.7	.....	34.7	.....	27.5	.....	28.3	.....	28.2	.....	29.0	.....	28.2	.....	23.3	.....	.....	.....	21.2	.....
20	33.3	.....	31.0	.....	67.5	.....	34.5	.....	.....	.....	.....	.....	.....	.....	61.5	.....	71.8	.....	.....	.....	.....	.....
21	36.8	1,995	60.9	2,820	48.6	3,261	63.5	3,540	62.8	3,210	51.9	2,700	60.4	2,940	63.7	3,240	.....	.....	69.0	3,600	.....	.....
22	32.5	.....	53.3	3,680	54.5	3,660	59 6	4,660	69.6	5,000	82.2	6,000	76 5	5,640	82 7	5,620	58.7	4,240	55.3	.....	43.1	.....
23	53.5	.....	52.0	.....	61.0	.....	54.5	.....	47.5	.....	48.5	.....	68.5	.....	75.5	.....	64.0	.....	.....	.....	40.0	.....
E	42.0	.....	49.2	.....	46.0	.....	59.0	.....	41.1	.....	58.0	.....	63.4	.....	60.8	.....	.....	.....	.....	.....	44.3	.....
25	40.0	3,700	50.6	4,240	42.2	41.40	41.1	4,700	57.0	4,340	60 0	5,880	37.0	5,640	60.0	5,540	37.5	4,240	51.4	.....	42.5	4,140
26	44.0	.....	60.0	.....	73.8	.....	56.2	.....	65.0	.....	57.5	.....	61 2	.....	81.2	.....	45 0	.....	.....	.....	.....	.....
Average	24 0	..	30.3	.....	36 0	.....	33 2	.....	38.6	.....	34.7	.....	40.1	.....	46.7	.....	29.1	.....	43.2	.....	27.5	..

Number.	Experimenters.	Surface soil.			Subsoil.	Previous cropping.	Weather.			Fertilizers, how applied.
		Kind.	Texture.	Moisture.						
1	John Flannagan, Kans	Clay		Dry	Clay	Corn	Warm	Dry	Unfavorable	Broadcast.
C	W I Bartholomew, Conn	Clay loam	Loose	Medium	Compact	Meadow	Cold	Wet	do	Hill.
3	John W Pierce, Mass	do	Compact	Dry	Gravelly hardpan	do	do	do	do	Hill and broadcast.
4	Burl Landon, Vt	Clay calc	do	do	Clay	do	do	Dry	Very unfav	Broadcast.
5	A P Arnold, N J	Sandy loam	Loose	do	Gravelly clay	Vineyard			Favorable	Do.
6	W C Atwood, Conn	do	do	Medium	Gravelly loam	Rye			do	Drill.
7	George Spalding, N H	Loam	do	do	Loam	Meadow	Cool		Unfavorable.	Broadcast.
8	F M Manning, Mass	Sandy loam	do	do	Sand	do	Variable.	Variable.	Favorable	Do.
9	Frank Bourne, Mass	Gravelly loam.	do	Dry	Gravelly and stony	Pasture.			do	Do.
F	J B Mead, Vt	Clay loam	Light	do	Compact	Oats	Cold		Very unfav	Do.
11	Zeno Benson, Mass	Loam	do	do	Loam	Pasture	Medium.	Medium	do	Do.
12	W S Stanton, Mass	Sandy loam	Loose	Medium.	Sand	Rye	Variable.	Variable.	Favorable	Drill.
13	C Miller & Son, Vt	do	Light	Dry		Meadow		Dry	Unfavorable	Broadcast.
14	J M Manning, Mass	do	do	Medium.	Sand	Fallow	Variable.	Variable.	Favorable	Do.
15	J A Cheden, Vt	do	do	do	Sandy loam	Meadow	do	do	do	Do.
16	E N Bissell, Vt	Clay loam	Compact.	Wet	Clay	do	Dry		Unfavorable	Do.
17	J. L. Dow, N. H	Loam	Light lse.	Dry	Hardpan	Corn	Cold		do	Hill.
18	W. Eliason, Md	Gravelly loam	Compact	do.	Clay	Grain			do	Do.
19	H. Pitts, D. C	Sandy loam	Light	do	do.	Pasture	Hot	Dry	Very unfav	Broadcast.
20	H. T. Stevens, N. Y.	Gravelly loam	Loose	do	Clay stony	Clover		do	do	Do.
21	H. M. Swift, N. Y.	do	do	do	Loose	Meadow	Warm		do	Hill.
22	Edward Hicks, N. Y	Sandy loam	Light	do	Loam	do			Favorable	Broadcast.
23	H. C. Loose, Md	Calcareous	Loose	do	Clay				do	Do.
E	Chester Sage, Conn	Gravelly loam.	Compact.	do	Loam	Meadow			do	Do.
25	James D Winslow, Vt	Sandy	Light	do	Sand	do	Variable.	Variable.	do	Do.
26	W H. Philbrook, N. H	Gravelly	do	do.	Gravelly	do			do	

* In experiments C, F, and E, 150 lbs., costing $5.62½. † In same experiments, 150 lbs., costing $3.37½.

‡ *Kinds and amounts of farm manure per acre.*—Experiment C, "hog manure, 20 cart loads"; 3, "stable manure, 7 cords"; 6, "yard manure, 15 cords"; 7, "stable manure, 4 cords"; 8, "stable manure and hog manure, 7½ cords;" 11, "hen manure, 240 pounds"; 13, "yard manure, 15 cords"; 14, "stable manure and hog manure, 9 cords;" 15, "yard manure 7½ cords"; 16, "stable manure, 20 loads"; 22, "stable manure, 6⅔ loads"; 25, "stable manure, 30 loads."

TABLE VII.—GENERAL EXPERIMENTS WITH POTATOES, TURNIPS, AND OTHER CROPS, 1879.

Yields per acre with different fertilizers.

Number of experiment.	Number of fertilizer.	0.	A.	B.	C.	D.	E.	F.	G.	H.		00.
	Fertilizers per acre.	No manure.	Nitrate of soda, 200 lbs.*	Dissolved bone-black, 300 lbs.	Muriate of potash, 200 lbs.†	Nitrate of soda, 150 lbs; dissolved bone-black, 300 lbs.	Nitrate of soda, 150 lbs; muriate of potash, 200 lbs.	Dissolved bone-black, 300 lbs; muriate of potash, 200 lbs.	Nitrate of soda, 150 lbs; dissolved bone-black, 300 lbs. muriate of potash, 200 lbs.	Plaster, 200 lbs.	Farm manures.	No manures.
	Cost per acre	.....	$7.50	$5.25	$4.50	$10.88	$10.13	$9.75	$15.38	$0.80	Variable	
27	Potatoes bu.	37	49	38	73	47	59	111	129	35	116	.....
C		38	32	62	33	96	42	98	109	.....	36	44
29		46	67	91	46	84	45	79	124	60	53	.....
30		37	45	136	49	117	44	145	172	41	.....	.....
31		150	180	175	215	220	260	360	370	150	470	.....
32		.....	133	152	140	.....	.....	.....	213	.....	182	.....
33		59	59	67	66	53	56	53	52	63	.....	66
34		40	56	52	72	54	66	88	98	60	50	.....
35		29	85	69	38	84	55	76	72	55	76	.....
36		80	105	110	175	94	125	80	145	90	120	.....
37		165	75	184	105	180	90	180	225	135	364	150
	Average of 9 experiments in 1879 (4)	50.7	75.3	88.8	85.2	93.2	83.6	121.1	141.2	69.2	131.6	55.0
	Oats:											
38	Grain bu.	15.6	15.3	45.6	10.0	58.7	54.4	28.1	40.0	27.8	26.9	.....
	Straw lbs.	1,640.0	2,046.0	4,400.0	1,100.0	6,440.0	5,860.0	3,380.0	5,760.0	3,120.0	2,720.0	.....
39	Grain bu.	23.1	31.9	32.5	25.6	45.0	30.0	31.9	43.7	22.5	.....	.....
40	Cotton lbs.	.....	.....	.....	.....	1,204.0	819.0	1,035.0	1,023.0	.....	.....	.....
41	Turnips do.	.....	.....	14,520.0	.....	9,070.0	.....	8,065.0	12,100.0	.....	14,520.0	.....
42	Beans bu.	4.0	3.2	3.8	2.2	4.7	3.9	3.5	5.0	4.5	4.3	.....

(*) In experiment C, 150 lbs., costing $5,62½. (†) In same experiment, 150 lbs., costing $3.37½. (‡) *Kinds and amounts of farm manures.*—Experiment 27, stable manure, 10 cords per acre; C, hog manure, 20 cart loads per acre; 31, stable manure, 9 cords per acre; 35, yard manure, 10 tons per acre; 36, stable manure, 30 loads per acre; 37, horse manure and hog manure, 3 cords per acre; 38, yard manure, 10 loads per acre; 41, yard manure; 42, stable manure, 15 cords per acre. (4) Nos. 32 and 37 not included in average.

Number.	Experimenters.	Surface soil.			Subsoil.	Previous cropping.	Weather.			Fertilizers, how applied.
		Kind.	Texture.	Moisture.						
27	Prof. W. H. Jordan, Me	Heavy clay	Compact	Wet	Heavy clay		Cold	Wet	Very unfavorable	Drill.
C	W. I. Bartholomew, Conn	Clay loam	Loose	Medium	Clay	Meadow	do	do	Unfavorable	Hill.
29	Zeno Benson, Mass	Loam	Light	Dry	Loam	Pasture	Warm	Variable	Favorable	Broadcast.
30	Edward M. Snow, Vt	Dark loom	Loose	do	Loam, compact	Oats	Variable	do	do	Hill.
31	Charles S. Cole, Vt	do	Medium			do				Broadcast.
32	Henry Arey, Mass	Sandy loom	Light	Dry	Yellow sand	Corn	Warm	Dry	Favorable	Hill.
33	E. G. Reist, Pa	Calcareous	Loose	Medium	Clay	do	Cold	do	Unfavorable	Broadcast.
34	John Labrunn, Mass	Calc. gravelly	Light, loose	Dry	Calc. gravelly	Pasture		Wet	do	Do.
35	P. W. Raidabaugh, Pa	Gravelly	Light	do	Clay		Variable	Dry	Very unfavorable	Drill.
36	Seth H. Rising, Vt	do	Loose	do	Gravelly		do		Unfavorable	Broadcast.
37	A. M. Foster, Vt	Dark loam	Light	do	Compact, stony	Meadow	Cool	Dry		Hill.
38	Dr. H. A. Cutting, Vt	Loam	do	do	Gravel		Cold	Wet	Unfavorable	
39	S. D. Burrows, N. J	Sandy loam	Loose	do	Clay and gravel			Dry	Favorable	Broadcast.
40	J. J. Deering, Ga	"Gray land"	Light	do	Porous	Cotton		Wet	Unfavorable	Drill.
41	H. M. Swift, N. Y	Grav. loam	Coarse	do	Open	Grapes	Warm		Favorable	
42	C. Miller & Son, Vt	Sandy loam	Light	do			do	Dry	do	

TABLE VIII.—GENERAL EXPERIMENTS WITH CORN, 1880.

Yields per acre with different fertilizers.

No. of experiments.	0.		A.		B.		C.		D.		E.		F.		G.		H.		00.		00.	
	No manure		Nitrate of soda, 200 lbs.*		Dissolved bone-black, 300 lbs.		Muriate of potash, 200 lbs.†		Nitrate of soda, 150 lbs.; dissolved bone-black, 300 lbs.		Nitrate of soda, 150 lbs.; muriate of potash, 200 lbs.†		Dissolved bone-black, 300 lbs.; muriate of potash, 200 lbs.†		Nitrate of soda, 150 lbs.; dissolved bone-black, 300 lbs.; muriate of potash, 200 lbs.†		Plaster, 200 lbs.		Farm manure.‡		No manure	
Cost per acre.			$7 50		$5 25		$4 50		$10 88		$10 13		$9 75		$15 38		$0 80		Variable.			
	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.	Corn.	Stalks.
	Bu.	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*	*Bu.*	*Lbs.*
1	10.1	.....	10.3	.....	23.0	.....	12.1	.....	27.4	.....	.....	.....	23.1	.....	31.0	.....	.....	.....	22.9	.....	9.7	.....
G	11.4	1,220	9.8	2,320	21.1	1,360	14.1	1,000	30.0	4,040	13.0	1,100	20.0	3,220	16.5	3,160	.....	.....	.....	.....	7.9	1,300
3	15.7	2,500	18.4	2,320	32.4	2,740	23.0	2,820	13.9	3,160	24.2	2,460	10.0	3,200	20.9	3,400	22.9	3,900	.....	.....	8.7	2,640
4	16.5	1,488	13.8	1,536	33.8	1,744	22.2	2,176	36.1	3,200	24.8	2,208	35.6	3,184	33.8	3,216	21.0	1,856	26.8	1,904	15.9	1,568
5	22.9	1,160	25.5	1,400	19.2	1,360	29.1	2,000	30.4	1,840	24.5	1,660	26.9	2,320	43.2	3,160	14.3	1,200	53.7	2,840	16.4	1,440
K	22.5	.....	42.5	.....	27.5	.....	25.0	.....	42.5	.....	45.0	.....	70.0	.....	52.5	.....	.....	.....	.....	.....	25.0	.....
7	26.5	.....	34.0	.....	37.0	.....	37.0	.....	42.3	.....	36.3	.....	32.5	.....	31.5	.....	26.5	.....	.....	.....	.....	.....
8	26.3	1,220	18.7	900	43.8	1,600	21.9	1,270	45.3	2,310	14.4	1,000	46.3	2,530	48.0	3,490	23.8	1,420	.....	.....	19.4	1,130
9	23.4	1,460	27.1	1,800	34.0	1,820	25.4	1,440	38.3	2,080	.....	.....	42.0	2,160	44.8	2,560	26.7	1,480	.....	.....	35.7	1,920
C	22.2	.....	20.1	.....	43.2	.....	24.7	.....	45.1	.....	24.0	.....	52.8	.....	50.0	.....	.....	.....	.....	.....	37.8	.....
11	30.0	.....	36.1	.....	45.6	.....	45.4	.....	48.4	.....	45.2	.....	48.2	.....	49.6	.....	36.5	.....	.....	.....	30.4	.....
12	35.0	.....	50.0	.....	51.5	.....	50.3	.....	57.5	.....	50.0	.....	52.5	.....	46.2	.....	50.0	.....	.....	.....	.....	.....
I	31.8	2,370	38.1	2,335	45.2	2,820	31.4	2,475	50.5	3,025	26.4	2,500	46.0	3,195	57.3	3,920	.....	.....	.....	.....	39.8	2,770
14	40.0	2,500	38.5	3,400	48.5	3,210	28.0	3,400	43.7	2,890	32.7	3,740	47.3	5,780	50.1	6,120	40.9	2,550	44.9	4,080	.....	.....
15	47.2	.....	50.0	.....	64.3	.....	61.4	.....	70.0	.....	55.7	.....	68.6	.....	64.3	.....	55.7	.....	67.5	.....	.....	.....
16	46.6	2,570	47.4	2,630	46.0	2,730	46.4	2,680	53.0	2,810	55.0	2,950	58.4	3,090	62.0	3,260	54.3	3,050	.....	.....	53.6	2,930
H	46.8	.....	50.3	.....	60.4	.....	67.8	.....	60.3	.....	72.0	.....	71.0	.....	70.0	.....	.....	.....	.....	.....	61.8	.....
18	50.0	3,160	48.3	2,900	55.6	3,500	50.0	3,240	58.3	3,500	53.6	3,340	58.3	3,540	57.8	4,280	57.5	3,400	63.9	4,000	52.8	3,400
19	56.5	.....	62.8	.....	68.7	.....	64.2	.....	76.4	.....	63.0	.....	68.6	.....	70.9	.....	58.4	.....	.....	.....	54.2	.....
20	61.7	.....	62.5	.....	73.3	.....	64.3	.....	67.0	.....	66.0	.....	72.5	.....	76.0	.....	68.0	.....	.....	.....	67.0	.....
Average	32.13	1,965	35.18	2,154	43.21	2,288	37.12	2,250	46.80	2,886	40.27	2,329	47.53	3,222	48.14	3,657	39.75	2,357	46.61	3,156	33.50	2,144

(*) In experiments G, K, C, I, and H 150 lbs., costing $5.62½. (†) In same experiments, 150 lbs., costing $1.50. (‡) *Kinds and amounts of farm manures.*—Experiment 1 stable manure, 20 loads; 5, stable manure, 500 cubic feet; 15, stable manure, 30 loads.

Yields per acre with other fertilizers.

No. 1. G CLENDON, Jr., Va. Finely ground raw South Carolina phosphate, 400 lbs. per acre. 20½ bushels per acre.
No. 9. J. W. PIERCE, Mass. Sulphate of magnesia, 300 lbs. per acre, 27.7 bushels; sulphate of magnesia, 200 lbs., and 20 bushels wood ashes, 47.7 bushels; superphosphate and muriate of potash, as F, with addition of 200 lbs. sulphate of magnesia, 40.9 bushels.
No. 12. H. GAYLORD, Conn. Wood ashes, 46.3 bushels.
No. 13. C. FAIRCHILD, Conn. Bone dust, 200 lbs., 42.3 bushels; bone dust, 200 lbs., and muriate of potash, 150 lbs., 47.3 bushels; lime, 2,000 lbs., 32.6 bushels. See full report of Mr. Fairchild's experiment, Appendix A.

Number	Experimenters.	Surface soil			Subsoil.	Previous cropping.	Weather			Fertilizers, how applied.
		Kind	Texture.	Moisture.						
1	Geo. Clendon, jr., Buckner's Station, Va.	Clay loam	Compact	Dry.	Red clay.	Corn (1)		Dry.	Favorable.	Broadcast
G	Prof. W. H. Jordan, Orono, Me.	do.	do.	Medium.	Clay.	Corn.		do.	Unfavor'ble.	Hill
3	A. P. Arnold, Vineland, N. J.	Sandy loam	Loose	Dry.	Sand and gravel.	Sweet potatoes.	Cool	do.	do.	Broadcast.
4	Prof. John R. Page, University of Va.	Sandy	do.	do.	Sand and clay.	Wheat.	do.	do.	do.	Do.
5	John M. Manning, Taunton, Mass.	Sandy loam	do.	Medium.	Yellow sand.	Corn.	Warm.	Wet.	Favorable.	Do.
K	Wm. C. Newton, Putnam, Conn.	Dark loam	Fine.	Moist.	Yellow loam.	Grass.			do.	Do.
7	C. G. Shenk, Bachmansville, Pa.	Sand and gravel.	Loose.	Dry.	Sand and gravel.	do.	Warm.	Dry.	Unfavor'ble.	Do.
8	R. P. Wolcott, Holland Patent, N. Y.	Sandy.	Light and loose.	do.	Sand.	Pasture.	do.	Moist.	Favorable.	Hill.
9	J. W. Pierce, West Milford, Mass.	Clay loam.	Compact.	do.	Clay and gravel.	Grass and corn.	do.	Dry.	do.	Broadcast.
C	W. I. Bartholomew, Putnam, Conn.	Clay.	Loose.	Medium.	Compact.	Corn.			do.	Drill.
11	Hiram Pitts, Washington, D. C.	Sandy or grav. loam.	Light.		Clay.	Grass.	Warm.	Dry.	do.	Broadcast
12	Henry Gaylord, Cheshire, Conn.	Sandy loam	Loose	Dry.	Gravelly loam.	Hay.	do.	do.	do.	Drill.
I	Chas. Fairchild, Middletown, Conn.	do.	Light and loose.	do.	Sand and gravel.	Pasture.	do.	do.	do.	Hill.
14	John H. Pann, Middleboro', Mass.	do.	do.	do.		Clover.		do.	do.	Drill.
15	Fairbanks & DeWitt, Rivings Mills, Md.	Clay and sand.	Compact.	Moist.		Corn.	Cool	Wet.	do.	Broadcast.
16	J. J. Wilson, Indiana.	Clay.	Heavy.	Wet.		do.			Unfavor'ble.	Do.
H	Edward Hicks, Old Westbury, N. Y.	Sandy loam	Loose.	Dry.	Yellow loam.	Pasture.		Dry.	Favorable.	Drill.
18	C. L. Kauffman, Downingsville, Pa.	do.	do.	do.	Gravelly.	Grass.	Warm.	Wet.	do.	Hill.
19	W. Elason, Chestertown, Md.	Gravelly loam	Compact.	do.	Clay.	Wheat.	do.	Dry.	do.	Do.
20	M. H. Dean, Falls Village, Conn.	Clay loam.	Heavy.	do.	Gravel.	Hay.		do.	do.	Broadcast.

TABLE IX.—EXPERIMENTS WITH POTATOES, TURNIPS, AND OTHER CROPS, 1880.

Yields per acre with different fertilizers.

Number of experiment.	Number of fertilizer.	O.	A.	B.	C.	D.	E.	F.	G.	H.		OO.
	Fertilizers per acre.	No manure.	Nitrate of soda, 200 lbs.*	Dissolved bone-black, 300 lbs.	Muriate of potash, 200 lbs.†	Nitrate of soda, 150 lbs.; dissolved bone-black, 300 lbs.	Nitrate of soda, 150 lbs.; muriate of potash, 200 lbs.†	Dissolved bone-black, 300 lbs.; muriate of potash, 200 lbs.†	Nitrate of soda, 150 lbs.; dissolved bone-black, 300 lbs.; muriate of potash, 200 lbs.†	Plaster, 200 lbs.	Farm manures.	No manure.
	Cost per acre		$7 50	$5 25	$4 50	$10 88	$10 13	$9 75	$15 88	$0 80	Variable.	
21	Potatoes bu.	29.3	28.0	64.7	29.3	76.7	27.7	104.0	127.3	39.7	101.3	34.7
22		72.5	71.7	100.2	72.0	109.2	57.3	98.0	.....	.....	.....	.....
23		46.0	51.0	46.0	46.5	48.5	46.0	50.0	41.0	41.0	.....	37.0
C		78.0	90.0	112.0	116.0	132.0	106.0	102.0	152.0	.....	.....	62.0
25		136.7	240.0	166.7	174.7	.....	.....	.....	260.0	200.0	.....	130.0
26		152.0	164.0	170.0	155.0	166.0	168.0	244.0	221.0	213.0	.....	166.0
	Average of 4 experiments in 1880 (1) bu.	76.3	83.3	98.2	86.7	105.8	99.4	125.0	135.3	97.9	101.3	74.9
27	Sweet potatoes bu.	132.8	158.4	152.4	188.4	172.0	200.0	208.0	222.0	.....	203.5	.....
	Oats:											
28	Grain bu.	20.9	20.8	22.5	23.4	23.2	25.6	27.2	27.8	21.9	.....	.....
	Straw lbs.	960	1,045	1,000	820	1,090	1,100	1,020	1,270	920	.....	.....
29	Turnips bu.	.....	.....	320	340	410	500	400	500	300	.....	270
30	Onions bu.	290	530	510	680	620	500	650	610	400	390	.....

* In experiment C, which is the same as reported in Table II, special nitrogen experiments, 150 pounds, costing $5.62½.
† In same experiment, 150 pounds, costing $3.37½. (1) In computing averages of potato experiments Nos. 22 and 25 are omitted.

Yields per acre with other fertilizers.

No. 21. J. M. MANNING, Bone-flour, 300 pounds + wood ashes, 25 bushels 39 bushels (stable manure 5,000 cubic feet), yield as per table.
No. 27. A. P. ARNOLD, N. J. 20 loads of stable manure, yield as per table.
No. 30. W. A. BENEDICT, Conn. 20 tons stable manure, yield as per table.

Number.	Experimenters.	Surface soil.			Subsoil.	Previous cropping.	Weather.			Fertilizers, how applied.
		Kind.	Texture.	Moisture.						
21	J. M. Manning, Taunton, Mass	Sandy loam	Light	Medium	Yellow sand	Grass	Variable	Variable		Broadcast.
22	E. B. Skeeves, Ives Grove, Wis	Black loam	do	Dry	Yellow clay	Flax	Warm	Wet	Variable	Drill.
38	E. C. Green Granger Ohio	Clayey loam	Loose	do	do	Corn	do	Dry	Very unfavorable.	Broadcast.
C	W. I. Bartholomew Conn	Clay	do	Medium	Compact	do			Favorable	Drill.
25	A. L. Wright, Peterboro Ont	Sandy	do	Dry	Gravel and sand	Wheat	Cool	Wet		Broadcast.
26	M. H. Dean Falls Village, Conn.	Clayey loam	Heavy	do	Heavy	Hay		Dry	Favorable	Do.
27	A. P. Arnold Vineland N. J	Sandy loam	Loose	do	Clay and gravel.	Sweet potatoes		do	do	Drill.
28	John C. Grundy Lewisburg, Pa	Red gravel		do	Red rock	Corn	Warm	do	Very unfavorable.	Broadcast.
29	M. H. Dean Conn	Clayey loam	Heavy	do	Gravelly	Hay		do	Favorable	
30	W. A. Benedict, Conn	do	do	Medium	Yellow clay	Onions	Warm	do	Unfavorable	Do.

TABLE X.—*Effects of individual ingredients of fertilizers, nitro*

EXPLANATION.—This table is intended to show (1) the regularity or irregularity of the action of the potash, and plaster in the different plots of each experiment. Thus, in No. B, the superphosphate, The figures are found by subtracting the yield without each ingredient in each case from the yields gives the effect of superphosphate alone. That of mixture of superphosphate and potash salts, less the results for each material on the several plots, gives the effect of that material in the experiment

Grouping of soils. (By yields without fertilizers. Heaviest soil of each group above and lightest below.)		Number of experiment.	Average yield unmanured.	INCREASE WITH NITROGEN. Nitrogen, 32 lbs., over no manure.	Nitrogen, 24 lbs., + phosphoric acid, over phosphoric acid alone.	Nitrogen, 24 lbs., + potash, over potash alone.	Nitrogen, 24 lbs., + phosphoric acid and potash, over phosphoric acid and potash.	Average increase from ni trogen
EXPERIMENTS								
Yielding less than 20 bushels of shelled corn per acre without manure.	Heavy clays to light sandy soils.	C	9.2	10.1	—5.3	6.6	13.7	6.3
		B	17.5	1.0	2.0	2.0	8.5	3.4
		2	7.0	10.5	6.2	5.8	—5.1	4.3
		3	6.5	—3.3	2.6	.....	5.2	1.5
		4	9.5	8.5	5.0	.....	8.0	7.0
		5	5.5	1.0	7.7	.....	4.0	3.2
		6	17.5	2.4	12.5	.....	5.0	6.0
		7	8.7	0.3	5.0	.....	3.7	2.9
		8	7.5	—2.0	8.0	.....	4.0	3.3
		9	5.0	6.0	7.5	8.5	5.0	6.8
		Average.	9.4	3.5	5.1	(5.5)	5.2	4.5
20–30 bushels shelled corn per acre without manure.	Heavy clays to light soils.	A	20.9	—3.6	17.7	10.0	2.8	6.7
		10	29.7	5.3	.....	.....	—2.5	1.3
		11	28.7	7.0	1.2	.....	9.3	5.8
		12	26.3	8.8	16.9	.....	18.7	13.1
		13	27.5	24.4	7.1	3.3	6.3	10.3
		14	20.2	20.3	10.5	7.0	—0.5	9.2
		15	20.5	23.2	2.6	—13.0	7.7	7.8
		16	24.0	—1.5	1.5	.....	—1.0	—0.2
		Average.	24.9	10.5	6.6	(3.0)	5.4	6.8
30–40 bushels unmanured	Heavy to light.	17	33.6	7.4	8.3	.....	10.0	8.0
		18	30.5	6.9	2.7	.....	.....	3.2
		19	33.0	—1.0	3.3	.....	0.4	1.2
		20	32.8	9.0	17.7	.....	7.5	11.4
		Average.	32.5	5.6	8.0	.....	4.5	6.0
Over 40 bushels unmanured.....	Heavier to lighter.	21	45.1	13.2	6.0	—20.3	11.0	1.6
		22	49.7	8.2	7.3	.....	1.0	6.4
		23	64.9	—1.8	1.2	4.8	11.3	4.0
		24	45.7	14.7	0.3	.....	18.7	10.1
		Average.	51.3	8.6	3.7	(—7.8)	10.5	5.5
Total averages of 26 experiments.		.....	.....	5.8	5.6	.....	5.7	5.7
EXPERIMENTS WITH								
Ranging from heavy clay to sandy loam.		25	137.5	—10.5	27.0	—14.0	23.0	6.4
		26	31.2	—0.4	8.8	.....	—0.8	2.5
		27	130.0	32.0	10.0	.....	30.0	24.0
		28	105.0	—0.3	45.0	.....	23.0	22.6
		29	60.0	16.6	6.6	.....	20.0	14.4
		30	133.0	6.0	11.0	—23.0	35.0	7.0
		31	141.0	—8.0	41.0	.....	22.9	18.6
		32	121.0	—4.0	8.0	.....	22.0	8.7
		33	32.5	7.5	20.0	40.0	40.0	26.9
Total averages of 9 experiments..		.....	.....	4.3	19.7	.....	23.9	14.6

*That is with superphosphate, which

gen, phosphoric acid (with sulphuric acid and lime), and potash.

different materials and (2) the specific effects of the substances furnishing nitrogen, phosphoric acid, and in No. C, the muriate of potash, is uniformly efficient. In No. 21 the results are very irregular. in the cases in which it was used. Thus, the yield with superphosphate alone, minus that with nothing, that with potash alone, gives the effect of superphosphate with potash salts, and so on. Averaging as a whole.

INCREASE WITH PHOSPHORIC ACID.						INCREASE WITH POTASH.				
Phosphoric acid, 48 lbs., over no manure.	Phosphoric acid, 48 lbs., + nitrogen, over nitrogen alone.	Phosphoric acid, 48 lbs., + potash, over potash alone.	Phosphoric acid, 48 lbs., + nitrogen, + potash, over nitrogen + potash.	Average increase from phosphoric acid.	Increase with plaster (= sulphuric acid and lime) over no manure.	Potash, 100 lbs., over no manure.	Potash, 100 lbs., + nitrogen, over nitrogen alone.	Potash, 100 lbs., + phosphoric acid, over phosphoric acid alone.	Potash, 100 lbs., + nitrogen, + phosphoric acid, over nitrogen + phosphoric acid.	Average increase from potash.
WITH CORN, 1878										
5.1	—10.3	8.0	15.1	6.0	.....	51.0	47.4	53.8	72.8	56.3
22.2	32.2	24.0	30.5	25.0	.....	1.4	2.4	3.2	9.7	4.2
3.3	—1.0	9.4	—1.5	2.6	7.4	2.2	—2.5	8.2	—0.3	1.3
26.5	22.4	16.4	.....	18.5	4.1	—0.7	.....	—0.8	—1.8	0.1
1.5	—2.0	6.0	.....	1.3	—0.5	32.5	24.0	37.0	40.0	33.0
5.2	16.9	6.7	.....	9.5	3.9	2.3	.....	3.8	2.1	2.1
16.0	26.3	12.5	.....	18.2	.....	8.5	.....	5.0	—2.5	5.7
8.8	13.5	8.8	.....	10.2	—1.7	—1.2	.....	—1.2	—2.5	—2.1
13.2	23.2	16.2	.....	17.5	.....	0.1	.....	3.1	1.3	0.5
2.5	6.0	6.5	.....	4.8	10.0	14.0	.....	17.5	16.0	13.8
9.5	12.7	11.5	(14.7)	11.3	1.8	11.1	17.7	13.0	13.6	11.5
6.2	17.7	7.4	—2.1	7.9	.....	10.6	23.6	10.9	2.8	12.4
7.5	.....	2.5	.....	3.3	—2.4	5.0	—25.0	.....	—2.5	.....
5.3	3.1	6.3	.....	6.1	3.8	2.8	.....	4.4	13.5	8.3
23.2	32.3	32.3	.....	29.2	29.3	8.8	.....	17.9	18.7	15.1
12.5	—4.8	—1.7	13.0	1.5	12.5	22.4	—0.5	9.9	6.6	9.9
37.0	27.4	41.0	33.5	34.7	2.8	10.0	—2.5	13.8	2.6	6.0
32.2	2.6	—6.5	15.1	6.9	12.5	19.4	—17.7	—10.3	—5.2	—3.4
5.5	13.5	11.5	.....	10.2	2.0	—3.5	.....	13.5	—1.0	3.0
16.2	11.5	11.7	(14.9)	12.5	8.6	9.4	0.1	7.5	4.4	6.4
0.4	1.2	—1.1	.....	—0.3	—1.6	11.6	.....	3.0	9.3	7.4
6.1	2.1	7.7	.....	5.3	0.5	4.5	.....	6.1	3.4	4.7
—1.0	2.4	0.3	10.0	2.9	—6.0	6.3	—2.0	8.6	5.6	6.2
.....	6.7	19.5	.....	8.7	6.2	12.5	.....	32.0	26.8	22.7
1.4	3.1	6.6	(19.0)	4.2	—0.2	8.7	—2.0	12.4	11.3	10.3
17.5	10.0	—11.0	20.6	8.4	—2.5	25.1	—8.4	—3.4	12.0	3.7
6.2	4.7	4.6	.....	6.1	3.3	8.6	.....	7.0	7.0	6.3
—0.2	2.4	4.8	11.5	6.2	0.8	—0.6	5.6	4.6	14.0	6.1
8.7	—6.3	19.5	.....	6.0	2.6	—7.5	....	3.8	21.7	4.4
8.1	2.7	15.3	(16.1)	6.7	1.1	5.1	—1.4	2.9	11.4	5.1
8.9	8.7	9.6	(9.0)	9.0	4.3	8.7	9.2	9.4	9.5	9.2
POTATOES, 1878.										
—9.5	27.0	—21.0	16.0	3.1	—5.5	—1.5	—5.0	—12.0	—16.0	—8.6
—2.8	6.4	7.4	.....	4.0	4.0	37.8	.....	48.0	38.4	41.4
70.0	48.0	95.0	.....	71.0	11.0	—5.0	.....	20.0	40.0	18.5
.....	48.0	22.0	.....	23.3	23.3	35.0	.....	57.0	35.0	42.3
40.0	30.0	56.7	.....	42.2	42.2	33.3	.....	50.0	63.4	48.9
5.0	10.0	5.0	63.0	20.8	20.8	16.0	—2.0	27.0	51.0	23.0
24.0	73.0	38.5	.....	45.2	45.2	65.0	.....	82.5	64.4	70.6
47.0	59.0	—69.0	.....	12.3	12.3	55.0	.....	—23.0	—9.0	7.7
47.5	60.0	80.0	80.0	66.9	66.9	67.5	20.0	20.0	40.0	49.2
24.6	40.2	23.8	.....	32.1	12.1	33.7	.....	29.9	34.1	32.6

had also some sulphuric acid and lime.

TABLE X—

Grouping of soils. (By yields without fertilizers. Heavier soil of each group above and lighter below.)		Number of experiment.	Average yield unmanured.	INCREASE WITH NITROGEN. Nitrogen, 32 lbs., over no manure.	Nitrogen, 24 lbs., + phosphoric acid, over phosphoric acid alone.	Nitrogen, 24 lbs., + potash, over potash alone.	Nitrogen, 24 lbs., + phosphoric acid and potash, over phosphoric acid and potash.	Average increase from nitrogen.
				EXPERIMENTS				
Yielding less than 20 bushels of shelled corn per acre without manure.	Heavier to lighter soils.	1	18.5	1.8	—1.1	—4.4	2.5	—0.3
		C	8.1	—0.7	4.9	—0.6	3.7	1.8
		3	3.3	—0.6	....	—1.2	—3.0	—1.2
		4	19.7	4.5	9.0	3.0	6.2	5.7
		5	3.7	[33.9]	15.2	9.5	—11.0	11.9
		6	8.0	6.7	15.4	8.8	40.0	17.2
		7	8.1	—1.3	1.1	0.1	4.9	1.2
		8	11.3	—0.1	2.3	—0.1	2.6	0.9
		9	12.5	25.0	—18.7	13.0	.....	4.8
		F	7.7	—1.5	13.5	—2.0	—7.2	0.7
		Av'ge.	9.2	6.7	4.1	2.4	4.3	4.1
20–30 bushels shelled corn per acre without manure.	Heavier to lighter soils.	11	23.9	—7.9	18.0	3.3	16.1	7.6
		12	14.3	8.0	17.0	19.7	—5.2	9.8
		13	21.9	5.6	—3.7	5.0	7.5	3.6
		14	22.7	13.8	5.1	—3.6	8.9	6.0
		15	25.4	3.4	3.7	—10.0	24.1	10.0
		Av'ge.	21.6	1.5	8.0	6.8	10.1	7.4
30–40 bushels unmanured.....	Heavier to lighter soils.	16	32.5	15.0	10.0	—13.8	.....	2.8
		17	41.0	3.0	—14.0	7.0	.....	—1.0
		18	34.0	—9.7	—0.1	—7.2	—12.9	—7.7
		19	25.8	10.1	—6.4	0.7	—0.8	—0.9
		20	33.0	—2.0	.....	.....	.....	—0.5
		21	36.8	24.1	14.2	—11.6	3.3	7.5
		22	37.8	15.5	15.1	22.6	6.2	18.5
		Av'ge.	34.3	8.0	2.7	—0.2	—0.6	2.7
Over 40 bushels unmanured.....	Heavier to lighter.	23	46.7	5.3	—14.5	—6.0	7.0	—2.0
		E	43.1	6.1	—4.9	—1.0	—2.6	—0.6
		25	41.7	17.9	14.8	18.9	23.0	18.4
		26	44.0	16.0	—8.8	1.3	20.0	7.1
		Av'ge.	43.8	11.3	—5.8	3.3	11.8	5.7
Average of 26 experiments.....		.....	24.0	6.3	1.7	2.5	5.5	4.6
				EXPERIMENTS				
Ranging from heavy clay to sandy loam.		27	37.0	12.0	9.0	—14.0	18.0	6.2
		C	46.0	4.0	36.0	6.0	15.0	13.2
		29	41.0	—9.0	32.0	9.0	11.0	10.8
		30	37.0	8.0	—19.0	—5.0	27.0	27.0
		31	150.0	30.0	45.0	45.0	10.0	32.0
		33	63.0	.....	—14.0	—10.0	—1.0	—6.2
		34	40.0	16.0	2.0	—6.0	10.0	5.5
		35	29.0	56.0	15.0	17.0	—4.0	21.0
		36	80.0	25.0	15.0	—50.0	65.0	13.7
		37	157.0	—90.0	—4.0	—15.0	45.0	—16.0
Total averages of 9 experiments..		.....	52.8	22 5	4.4	—1.6	20.1	11.3

ontinued.

INCREASE WITH PHOSPHORIC ACID (plus sulphuric acid and lime).					INCREASE WITH PLASTER.	INCREASE WITH POTASH.				
Phosphoric acid, 48 lbs., over no manure	Phosphoric acid, 48 lbs., + nitrogen, over nitrogen alone	Phosphoric acid, 48 lbs., + potash, over potash alone.	Phosphoric acid, 48 lbs., + nitrogen, + potash, over nitrogen + potash.	Average increase from phosphoric acid.	Sulphuric acid and lime, over no manure.	Potash, 100 lbs., over no manure.	Potash, 100 lbs., + nitrogen, over nitrogen alone.	Potash, 100 lbs., + phosphoric acid, over phosphoric acid alone.	Potash, 100 lbs., + nitrogen, + phosphoric acid, over nitrogen + phosphoric acid.	Average increase from potash.
WITH CORN, 1879.										
1.8	—1.1	0.3	7.2	2.0	—5.5	—1.2	—7.4	—2.7	0.9	—2.6
28.4	34.0	34.3	38.6	33.9	.....	—0.4	—0.3	5.5	4.3	2.2
8.7	9.3	10.0	8.2	9.0	—4.6	—3.4	2.8	4.7	1.7	3.1
2.6	7.1	16.2	19.4	11.3	11.1	—3.7	—9.8	—4.9	2.1	6.5
10.9	—7.8	3.2	0.4	1.7	—28.0	3.2	—19.2	—4.5	11.6	—7.9
15.3	24.0	10.8	42.0	23.0	2.6	21.4	23.5	16.9	41.5	25.8
11.6	10.9	11.3	16.1	12.9	11.1	1.9	3.7	5.1	8.9	4.9
5.3	7.7	2.3	5.9	5.2	—6.8	—0.3	—1.2	—3.3	—2.0	—1.9
28.7	—15.5	20.0	7.0	10.2	25.9	12.5	0.5	3.8	22.5	9.8
—6.3	13.7	9.6	3.6	6.5	.....	33.6	32.5	48.3	22.6	33.0
11.3	7.2	11.7	14.8	11.5	0.6	8.3	2.9	7.8	[illegible]	6.3
2.3	28.2	10.4	23.3	16.0	—4.9	—12.9	—1.7	—4.8	—6.7	—6.5
6.7	14.7	.....	—24.9	—6.9	—0.8	10.3	22.0	4.6	—17.6	4.8
11.8	2.5	7.5	10.0	7.9	12.6	1.8	1.2	—2.5	8.7	3.3
26.7	18.2	10.4	22.9	19.5	.....	23.0	5.8	6.7	10.5	11.5
3.4	16.3	—3.7	10.4	5.1	12.6	11.7	25.1	5.2	25.2	16.7
10.2	14.7	6.1	10.1	9.5	4.6	6.7	10.6	1.8	4.0	5.7
7.5	2.5	—12.5	—1.3	—0.9	—2.5	22.5	—6.3	2.5	—8.8	2.7
43.0	26.0	21.0	14.0	26.0	3.0	2.0	6.0	—20.0	—6.0	—4.5
11.7	21.3	17.0	11.3	15.3	12.2	—2.4	0.1	2.9	—9.9	2.1
8.1	—7.4	1.5	.....	0.2	2.3	2.1	7.5	—5.7	—0.1	0.4
34.5	.....	.....	.....	8.6	38.8	1.5	.....	.....	.....	0.4
11.8	1.9	—3.1	11.8	5.6	6.1	26.7	—8.0	11.8	0.9	12.6
14.7	16.3	16.9	0.5	13.9	29.9	21.8	26.9	22.0	13.1	22.7
14.4	8.6	5.6	9.4	9.6	10.7	10.6	3.9	1.6	—1.5	4.5
14.3	—4.5	14.0	27.0	12.7	17.3	7.8	—3.5	7.5	28.0	9.7
2.9	—8.1	4.4	2.8	0.4	.....	15.9	8.8	17.4	19.7	15.4
6.5	—2.6	0.9	.....	0.4	—4.2	—0.6	—0.4	—7.5	3.0	—1.4
28.8	5.0	5.0	23.7	14.9	1.9	12.2	—2.5	—12.6	16.2	3.3
11.8	2.5	6.1	17.5	7.1	2.5	8.8	—0.6	1.2	16.7	6.8
12.9	8.3	8.1	11.7	10.2	6.1	8.7	4.1	3.7	8.1	6.2
WITH POTATOES, 1879.										
1.6	—2.0	38.0	70.0	[illegible]	2.0	36.0	10.0	73.0	62.0	56.2
32.0	72.0	69.0	78.0	62.7	.....	.....	10.0	37.0	16.0	15.7
21.0	64.0	65.0	67.0	54.3	14.0	—8.0	10.0	38.0	13.0	12.7
98.0	72.0	98.0	128.0	98.7	4.0	12.0	—1.0	9.0	55.0	18.7
25.0	40.0	145.0	110.0	80.0	0.0	65.0	80.0	185.0	150.0	128.0
4.0	—8.0	—12.0	—4.0	—4.7	4.0	3.0	—3.0	14.0	—1.0	—3.7
12.0	—2.0	16.0	32.0	14.5	20.0	32.0	10.0	36.0	44.0	40.5
98.0	—1.0	28.0	17.0	23.5	26.0	2.0	—30.0	7.0	—12.0	—6.5
30.0	—11.0	—85.0	20.0	—14.0	10.0	95.0	26.0	—30.0	51.0	3.4
27.0	105.0	75.0	35.0	60.5	[illegible]	—60.0	15.0	—4.0	45.0	—1.6
36.0	17.0	35.9	57.6	[illegible]	16.4	32.4	7.3	32.3	48.0	30.2

TABLE X—

Grouping of soils.	Number of experiment.	Average yield unmanured.	INCREASE WITH NITROGEN. Nitrogen, 32 lbs., over no manure.	Nitrogen, 24 lbs., + phosphoric acid, over phosphoric acid alone.	Nitrogen, 24 lbs., + potash, over potash alone.	Nitrogen 24 lbs., + phosphoric acid and potash, over phosphoric acid and potash.	Average increase from nitrogen.
EXPERIMENTS WITH							
Arranged in order of yield on unfertilized plots.	1	9.7	—1.6	8.9	1.9	.....	3.1
	G	9.9	0.4	4.4	.....	7.9	4.2
	3	12.2	3.4	—18.5	2.8	10.9	—0.4
	4	16.2	—4.1	—5.0	1.1	0.0	2.1
	5	19.6	3.3	12.6	—3.2	0.7	3.4
	K	23.8	19.9	14.7	19.7	30.0	21.1
	7	26.5	7.5	5.3	—6.0	0.0	1.7
	8	28.0	—6.9	3.0	—6.0	2.5	—1.9
	9	29.6	0.6	0.2	.....	5.1	1.5
	C	30.0	—2.1	—0.3	—5.1	—5.1	—3.2
	11	30.2	5.6	2.8	—0.2	1.4	2.4
	12	35.0	15.0	6.0	—0.3	—6.3	3.6
	I	36.4	5.2	4.1	—4.9	10.0	3.6
	14	40.0	13.3	5.2	4.7	—9.2	3.6
	15	47.2	2.8	5.7	—5.7	—4.3	—0.4
	16	50.1	—2.7	7.2	1.3	3.5	2.3
	H	51.8	—3.5	0.0	4.2	—1.0	1.7
	18	52.0	—3.7	2.9	3.6	—0.5	0.6
	19	55.3	7.4	8.2	—1.2	2.3	4.2
	20	64.3	—1.6	—5.9	1.7	3.5	—0.6
Average of 26 experiments		33.4	2.9	3.1	0.4	2.7	2.6
EXPERIMENTS WITH							
	21	32.0	—1.8	10.8	—2.5	22.9	7.4
	22	72.5	5.2	9.0	—15.1	.....	—0.3
	23	44.7	5.3	2.6	—0.6	—0.4	1.7
	C	78.0	12.0	0.0	—4.0	38.0	11.5
	25	152.8	89.5	.....	.....	.....	89.5
	26	159.0	10.4	2.9	9.9	—24.5	—0.3
Average of 4 experiments		76.4	6.5	4.6	1.8	9.3	5.6
EXPERIMENTS WITH							
	27	117.6	21.7	12.1	4.0	10.2	12.0
EXPERIMENTS							
	28	20.9	—0.5	0.6	2.2	0.6	0.7
		960.0	85.0	90.0	280.0	250.0	176.0
EXPERIMENTS							
	29	270.0	.....	90.0	160.0	100.0	117.0
EXPERIMENTS							
	30	290.0	240.0	90.0	180.0	—40.0	117.5

Continued.

INCREASE WITH PHOSPHORIC ACID (plus sulphuric acid and lime).					INCREASE WITH PLASTER.	INCREASE WITH POTASH.				
Phosphoric acid, 48 lbs., over no manure.	Phosphoric acid, 48 lbs., + nitrogen, over nitrogen alone.	Phosphoric acid, 48 lbs., + potash, over potash alone.	Phosphoric acid, 48 lbs., + nitrogen, + potash, over nitrogen + potash.	Average increase from phosphoric acid.	Sulphuric acid and lime, over no manure.	Potash, 100 lbs., over no manure.	Potash, 100 lbs., + nitrogen, over nitrogen alone.	Potash, 100 lbs., + phosphoric acid, over phosphoric acid alone.	Potash, 100 lbs., + nitrogen + phosphoric acid, over nitrogen + phosphoric acid.	Average increase from potash.
CORN, 1880.										
9.7	20.2	9.9	.....	13.3	.....	0.3	2.2	−1.1	.....	0.3
13.1	17.1	11.0	.....	13.7	.....	2.2	.....	0.1	3.7	.....
18.1	−2.2	−10.6	−2.8	0.6	13.3	9.5	8.9	−19.2	8.3	1.9
14.5	18.1	13.1	11.4	14.3	2.5	1.5	6.7	0.1	0.0	2.1
−2.2	7.1	0.1	3.8	2.2	−2.8	8.4	1.9	10.5	1.4	5.6
4.8	−0.4	−3.0	7.3	2.2	.....	2.2	2.0	−5.2	9.7	3.7
10.5	8.3	−5.5	−4.8	2.1	0.0	10.5	2.3	−5.5	−10.8	−0.9
19.0	28.9	26.7	35.2	27.5	3.6	−2.1	−1.2	5.6	5.1	1.9
8.6	8.2	13.3	.....	10.0	−4.9	−2.1	.....	2.6	7.5	2.7
21.0	22.8	21.4	21.4	21.7	.....	2.5	−0.5	2.9	−1.9	0.8
15.4	12.6	2.8	4.4	8.8	6.3	15.2	9.4	2.6	1.2	7.1
16.5	17.5	2.2	−3.8	8.1	15.0	15.3	0.0	1.5	−11.3	1.1
12.2	11.1	14.3	30.2	17.0	.....	−2.4	−2.1	−0.3	6.6	0.5
8.5	5.2	19.3	17.4	12.6	0.9	−12.0	−5.8	−1.2	6.4	−3.2
17.1	20.0	7.2	8.6	13.2	10.5	14.2	5.7	4.3	−5.7	4.6
−4.1	5.8	4.7	6.9	3.3	4.2	3.7	7.7	12.5	8.8	8.2
13.6	10.0	3.2	−2.0	8.3	.....	21.0	21.7	10.6	9.7	15.8
3.4	10.0	8.3	4.2	6.5	5.5	−2.0	5.3	10.0	−0.5	3.2
13.4	14.2	4.4	7.9	10.0	3.1	8.9	0.3	−0.1	−6.0	0.8
9.0	4.7	8 2	10.0	8.0	3.7	0.0	3.3	−0.8	8.6	2.8
11.1	12.0	7.5	8.6	10.2	4.4	4.7	3.8	1.5	4.0	3.1
POTATOES, 1880.										
34.8	46.4	72.9	98.3	63.1	6.3	−1.4	−2.1	36.7	48.8	20.5
33.8	37.6	26.4	.....	32.6	.....	5.5	−14.8	−1.9	.....	3.7
−0.3	2.4	3.4	−4.4	0.4	−4.7	0.9	−5.0	4.0	1.8	0.4
34.0	22.0	−2.0	40.0	23.5	.....	38.0	22.0	2.0	40.0	25.5
2.3	.....	.....	.....	2.3	28.7	3.5	.....	.....	.....	3.5
4.9	−2.6	84.3	49.9	34.1	48.5	−1.7	−2.2	77.7	50.3	31.0
18.5	17.6	46.6	47.1	31.7	12 5	9.0	4.3	32.1	39.5	23.2
SWEET POTATOES, 1880.										
12.0	2.4	8.3	14.5	9.3	.....	44.3	26.6	40.6	38.7	37.6
WITH OATS, 1880.										
1.6	2.7	3.8	2.2	2.6	−0.9	2.5	5.2	4.7	4.7	4.3
40.0	45.0	200.0	170.0	114.0	−40.0	−140.0	55.0	20.0	180.0	29.0
WITH TURNIPS, 1880.										
50.0	.....	60.0	0.0	36 7	30 0	70.0	180 0	80.0	90.0	105.0
WITH ONIONS, 1880.										
220.0	90.0	−30.0	110.0	97.5	110.0	390.0	−30.0	140.0	−10.0	122.5

TABLE X—

	Number of experiment.	Average yield unmanured.	INCREASE WITH NITROGEN. Nitrogen, 32 lbs., over no manure.	Nitrogen, 24 lbs., + phosphoric acid, over phosphoric acid alone.	Nitrogen, 24 lbs., + potash, over potash alone.	Nitrogen, 24 lbs., + phosphoric acid and potash, over phosphoric acid and potash.	Average increase from nitrogen.
EXPERIMENTS							
	C	7.3	1.2	4.3	—4.5	3.6	1.2
	L	12.5	10.0	10.0	8.8	9.5	9.6
	M	38.2	—2.3	—2.8	0.0	2.8	—0.6
	N	40.0	4.3	1.7	—3.7	—2.9	—0.6
	O	10.3	1.4	—1.7	5.3	—0.6	1.1
	P	16.3	9.7	1.7	—5.0	0.8	1.8
	Q	44.7	8.4	10.4	—8.4	—0.2	2.5
Average of 7 experiments		24.2	4.7	3.4	0.0	1.9	2.6
EXPERIMENTS							
	C, '81	44.0	4.0	0.0	2.0	26.0	8.0
	I, '81	28.0	14.0	38.7	8.0	34.0	23.7
	M, '81	12.8	29.9	—32.0	—3.2	24.7	4.9
Average of 5 experiments		28.2	15.9	2.2	2.2	28.2	12.2
EXPERIMENTS							
	I, '81	26.9	11.2	18.1	11.2	20.6	15.3
EXPERIMENTS							
	R, '81	587	218	437	368	322	336
EXPERIMENTS							
	S, '81	480	220	—120	—380	60	—56

Concluded.

INCREASE WITH PHOSPHORIC ACID (plus sulphuric acid and lime).					INCREASE WITH POTASH.				
Phosphoric acid, 48 lbs., over no manure.	Phosphoric acid, 48 lbs., + nitrogen, over nitrogen alone.	Phosphoric acid, 32 lbs., + potash, over potash alone.	Phosphoric acid, 48 lbs., + nitrogen, + potash, over nitrogen + potash.	Average increase from phosphoric acid.	Potash, 100 lbs., over no manure.	Potash, 100 lbs., + nitrogen, over nitrogen alone.	Potash, 100 lbs., + phosphoric acid, over phosphoric acid alone.	Potash, 100 lbs., + nitrogen + phosphoric acid over nitrogen + phosphoric acid.	Average increase from pot.
WITH CORN, 1881.									
5.1	8.2	15.2	28.3	12.9	2.7	—3.0	12.8	12.1	6.1
19.0	1.3	—1.3	—0.5	2.4	2.5	1.3	0.9	—0.5	4.3
—1.8	—2.3	0.0	2.8	—0.3	—2.7	—2.3	—1.9	2.7	—1.0
8.5	6.0	2.4	6.2	5.5	6.6	0.6	2.4	—1.2	2.3
5.7	2.6	18.9	11.0	9.0	7.4	11.3	13.6	19.7	14.3
6.5	—1.5	—6.3	9.5	0.4	13.2	3.5	5.4	4.4	7.9
6.5	8.5	7.0	15.2	9.3	7.3	—9.5	7.3	—2.3	0.7
[illegible]	3.3	5.0	7.9	5.5	6.1	—1.2	6.5	5.1	4.2
WITH POTATOES, 1881.									
14.0	10.9	24.9	48.0	24.0	5.0	4.0	16.0	42.0	17.0
28.0	52.7	30.7	58.7	42.0	32.0	16.0	34.7	30.7	28.4
4.3	—32.0	4.3	32.7	3.4	3.7	—36.3	—3.3	37.9	—2.1
15.4	10.2	19.3	45.8	22.8	13.9	—5.6	15.8	38.5	14.4
WITH OATS, 1881.									
6.9	13.8	2.5	11.9	8.8	4.4	4.4	0.0	2.5	2.8
WITH COTTON, 1881.									
575	794	665	669	658	—23	127	57	—58	26
WITH CLOVER, 1881.									
720	389	200	640	485	460	—140	—60	190	95

TABLE XI.—*Effects of individual ingredients.*

[Selected experiments.]

Date.	Number of experiment.	Average yield unmanured.	INCREASE WITH NITROGEN.					INCREASE WITH PHOSPHORIC ACID (plus sulphuric acid and lime).					INCREASE WITH PLASTER.	INCREASE WITH POTASH.				
			Nitrogen, 32 lbs., over no manure.	Nitrogen, 24 lbs., + phosphoric acid, over phosphoric acid alone.	Nitrogen, 24 lbs., + potash, over potash alone.	Nitrogen, 24 lbs., + phosphoric acid and potash, over phosphoric acid and potash.	Average increase from nitrogen.	Phosphoric acid, 48 lbs., over no manure.	Phosphoric acid, 48 lbs., + nitrogen, over nitrogen alone.	Phosphoric acid, 48 lbs., + potash, over potash alone.	Phosphoric acid, 48 lbs., + nitrogen, + potash, over nitrogen + potash.	Average increase from phosphoric acid.	Sulphuric acid and lime, over no manure.	Potash 100 lbs., over no manure.	Potash, 100 lbs., + nitrogen, over nitrogen alone.	Potash, 100 lbs., + phosphoric acid, over phosphoric acid alone.	Potash, 100 lbs., + nitrogen + phosphoric acid, over nitrogen + phosphoric acid.	Average increase from potash.
EXPERIMENTS WITH CORN.																		
1878	D	9.2	10.1	—5.3	6.6	13.7	6.3	5.1	—10.3	8.0	15.1	6.0	.....	51.0	47.4	53.8	72.8	56.3
	B	17.5	1.0	2.0	2.0	8.5	3.4	22.2	32.2	24.0	30.5	25.0	.....	1.4	2.4	3.2	9.7	4.2
	3	6.5	—3.3	2.6	0.0	5.2	1.5	16.5	22.4	16.4	.....	18.5	4.1	—0.7	.....	—0.8	—1.8	0.1
	4	9.5	8.5	6.0	.....	8.0	7.0	1.5	—2.0	6.0	.....	1.3	—0.5	32.5	24.0	37.0	40.0	33.0
	8	7.5	—2.0	8.0	.....	4.0	3.3	13.2	23.2	16.2	.....	17.5	.....	0.1	.....	8.1	1.3	0.5
	9	5.0	6.0	7.5	8.5	5.0	6.8	3.5	6.0	6.5	.....	4.8	10.0	14.0	.....	17.5	16.0	13.8
	12	26.3	8.8	16.9	.....	18.7	13.1	23.2	32.3	32.3	.....	29.2	29.3	8.8	.....	17.9	18.7	15.1
1879	C	8.1	—0.7	4.9	—0.6	3.7	1.8	28.4	34.0	34.3	38.6	33.8	.....	—0.4	—0.3	5.5	4.3	2.2
	6	8.0	6.7	15.4	8.8	40.0	17.2	15.3	24.0	10.8	42.0	23.0	2.6	21.4	23.5	16.9	41.5	25.8
	7	8.1	—1.3	1.1	0.1	4.9	1.2	11.6	10.9	11.3	16.1	12.9	11.1	1.9	3.7	5.1	8.9	4.9
	F	7.7	—1.5	13.5	—2.0	—7.2	0.7	0.3	13.7	9.0	3.8	6.5	.....	33.6	32.5	43.3	22.6	33.0
	14	22.7	13.8	5.1	—3.6	8.9	6.0	26.7	18.2	10.4	22.9	19.5	.....	23.0	5.8	6.7	10.5	11.5
	22	37.8	15.5	15.1	22.6	6.2	18.5	16.7	16.3	16.9	0.5	13.5	20.9	21.8	28.9	22.0	13.1	22.7
	E	43.1	6.1	—4.9	—1.0	—2.6	—0.6	2.9	—8.1	4.4	2.8	0.4	.....	15.9	8.8	17.4	19.7	15.4
	25	41.7	17.9	14.8	18.9	23.0	18.4	0.5	—2.6	0.9	0.0	0.4	—4.2	—0.6	—0.4	—7.5	3.0	—1.4
1880	K	23.8	19.9	14.7	19.7	30.0	21.1	4.8	—0.4	—3.0	7.3	2.2	.....	2.2	2.0	—5.2	9.7	3.7
	C	30.0	—2.1	—0.3	—5.1	—5.1	—3.2	21.0	22.8	21.4	21.4	21.7	.....	2.5	—0.5	2.9	—1.9	0.8
	11	30.2	5.6	2.8	—0.2	1.4	2.4	15.4	12.6	2.8	4.4	8.8	6.3	15.2	9.4	2.6	1.2	7.1
	15	47.2	2.8	5.7	—5.7	—4.3	—0.4	17.1	20.0	7.2	8.6	13.2	10.5	14.2	5.7	4.3	—5.7	4.6
	H	51.8	—3.5	0.0	4.2	—1.0	1.7	13.6	10.0	3.2	—2.0	8.3	.....	21.0	21.7	10.6	9.7	15.8
	19	55.3	7.4	8.2	—1.2	2.3	4.2	13.4	14.2	4.4	7.9	10.0	3.1	8.9	0.8	—0.1	—6.0	0.8
1881	C	7.3	1.2	4.3	—4.5	3.6	1.2	5.1	8.2	15.2	23.3	12.9	.....	2.7	—3.0	12.8	12.1	6.1
	L	12.5	10.0	10.0	8.8	9.5	9.6	10.0	1.3	—1.2	—0.5	2.4	.....	2.5	1.3	2.0	—0.5	0.8
	O	10.3	1.4	—1.7	5.3	—0.6	—1.1	5.7	2.6	16.9	11.0	9.0	.....	7.4	11.3	18.6	19.7	14.3
Average.....		21.9	4.7	5.8	8.4	7.3	5.8	12.1	12.1	11.4	10.2	12.1	8.9	12.1	9.1	12.0	18.2	12.1

1878	26	31.2	—0.4	8.8	.....	0.8	2.5	—2.8	6.4	7.4	.....	4.0	4.0	37.8	.....	48.0	38.4	41.4
	27	130.0	32.0	10.0	.....	80.0	24.0	70.0	48.0	95.0	.....	71.0	11.0	—5.0	.....	20.1	40.0	18.5
	28	105.0	—0.3	45.0	.....	23.0	22.6	00.0	48.0	22.0	.....	28.3	28.3	35.0	.....	57.0	35.0	42.3
	29	60.0	16.6	6.6	.....	20.0	14.4	40.0	30.0	56.7	.....	42.2	42.2	33.3	.....	50.0	63.4	48.9
	31	141.0	—8.9	41.0	.....	22.9	18.6	24.0	78.0	88.5	.....	45.2	45.2	65.0	.....	82.5	64.4	70.6
	33	82.5	7.5	20.0	40.0	40.0	26.9	47.5	60.0	80.0	80.0	66.9	66.9	67.5	20.0	20.0	40.0	49.2
1879	31	150.0	30.0	45.0	45.0	10.0	32.0	25.0	40.0	145.0	110.0	80.0	.....	65.0	80.0	185.0	150.0	120.0
	34	40.0	16.0	2.0	—6.0	10.0	5.5	12.0	—2.0	16.0	32.0	14.5	20.0	32.0	10.0	36.0	44.0	40.5
1880	21	32.0	—1.8	10.8	—2.5	22.9	7.4	34.8	46.4	72.9	98.3	63.1	6.3	—1.4	—2.1	36.7	48.8	20.5
	C	70.0	12.0	2.0	0.5	39.3	18.5	34.0	24.2	5.8	44.6	27.2	.....	38.0	26.5	9.8	46.9	30.8
1881	C	44.0	4.0	0.0	2.0	26.0	8.0	14.0	10.0	24.0	48.0	24.0	.....	6.0	40.0	16.0	42.0	17.0
	I	28.9	14.0	38.7	8.0	34.0	23.7	28.0	52.7	—30.7	56.7	42.0	.....	32.0	16.0	34.7	30.7	28.4
Average	....	68.4	10.2	19.1	7.2	26.2	16.6	27.1	36.4	32.7	39.1	41.1	18.4	28.3	15.8	49.6	58.6	44.0

	Kinds and amounts of fertilising materials applied per acre.	0. No manure.	A. Nitrate of soda, 200 lbs.	B. Dissolved bone-black, 300 lbs.	C. Muriate of potash, 200 lbs.	D Nitrate of soda, 150 lbs.; dissolved bone-black 300 lbs.	E. Nitrate of soda, 150 lbs.; muriate of potash, 200 lbs.	F. Dissolved bone-black, 300 lbs.; muriate of pot-ash, 200 lbs.	G. Nt. of soda, 150 lbs.; dis. bone-black, 300 lbs.; mu. of potash, 200 lbs.	H. Plaster, 200 lbs.	Farm manures.
	AVERAGE PRODUCE PER ACRE.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Corn	27 experiments in 1878	24.6	30.4	33.5	33.3	39.1	39.6	42.9	48.6	28.9	45.9
	26 experiments in 1879	24.0	30.3	36.9	33.2	38.6	34.7	40.1	46.7	29.1	43.2
	20 experiments in 1880	32.1	35.2	43.2	37.1	46.8	40.3	47.5	48.1	39.8	46.6
	7 experiments in 1881	24.2	28.8	28.7	30.3	33.5	29.2	35.3	37.1	.....	.....
	80 experiments in 1878–'81	26.2	31.4	36.6	34.0	40.3	37.2	42.5	46.8	.....	.....
Potatoes	9 experiments in 1878	100.0	103.0	123.4	129.6	143.2	106.0	153.4	177.3	106.0	182.9
	9 experiments in 1879	58.2	76.4	90.7	86.5	96.3	84.7	123.0	143.6	69.3	131.6
	4 experiments in 1880	76.3	83.3	98.2	86.7	105.8	99.4	125.0	135.3	97.9	101.3
	3 experiments in 1881	28.2	44.2	43.7	39.7	54.4	41.9	59.5	87.7	.....	.....
	25 experiments in 1878–'81	72.5	83.2	98.0	96.4	109.6	89.6	130.8	147.7	.....	.....
	Average of the experiments in which farm manures were used:										
	Corn, 43 experiments:										
	Average produce	24.8	30.2	34.9	38.0	40.6	25.1	41.8	47.7	26.3	45.3
	Average increase	.....	5.4	10.1	13.2	15.8	0.3	17.0	22.9	1.5	20.5
	Potatoes, 15 experiments:										
	Average produce	72.1	80.2	95.0	103.3	112.4	87.7	128.9	154.6	84.1	130.1
	Average increase	.....	8.1	22.9	31.2	40.3	15.6	56.8	82.5	12.0	58.0
Sweet potatoes	5 experiments	71.2	133.9	102.3	164.3	124.5	195.2	164.9	214.2	(60.0)	272.7
Turnips	3 experiments	.....	425.0	416.7	387.7	477.0	454.0	489.7	601.0	412.0	440.0
Sugar beets	1 experiment	795.0	1,013.0	1,174.0	851.0	1,116.0	988.0	1,091.0	1,119.0	961.0	.....
Onions	1 experiment	290.0	530.0	510.0	680.0	620.0	500.0	650.0	610.0	400.0	390.0
Oats	4 experiments	21.6	25.0	36.1	22.6	47.7	38.1	30.2	41.5	.....	.....
Cotton	1 experiment	587.0	865.0	1,162.0	564.0	1,599.0	982.0	1,219.0	1,541.0	.....	.....
Clover	1 experiment	480.0	700.0	1,200.0	940.0	1,080.0	560.0	1,140.0	1,200.0	.....	.....
	AVERAGE INCREASE PER ACRE.										
Corn	80 experiments	.....	5.2	10.4	7.8	14.1	11.0	16.3	20.6	.....	.....
Potatoes	25 experiments	.....	9.3	25.5	23.9	37.1	17.1	56.3	75.2	.....	.....
Oats	4 experiments	.....	3.4	14.5	1.0	26.1	16.5	8.6	19.9	.....	.....

Sweet potatoes	5 experiments	.....	59.4	27.8	89.8	50.0	120.7	90.2	139.7	—14.5	[illegible]
Turnips	8 experiments	.....	220.4	212.1	183.1	273.4	249.4	285.1	396.4	207.4	235.4
Sugar beets	1 experiment	.....	218.0	379.0	56.0	321.0	193.0	294.0	328.0	164.0	.....
Onions	1 experiment	.....	240.0	240.0	390.0	330.0	210.0	360.0	320.0	110.0	100.0
Cotton	1 experiment	.....	278.0	575.0	—23.0	1,012.0	345.0	632.0	954.0	.....	.....
Clover	1 experiment	.....	220.0	720.0	460.0	600.0	80.0	660.0	720.0	.....	.....

TABLE XIII, PART I.—RECAPITULATION OF EXPERIMENT ON EFFECTS OF NITROGENOUS FERTILIZERS UPON CORN AND POTATOES.

[Increase in yield with mineral plus nitrogenous fertilizers over mineral fertilizers alone.]

"Mixed minerals" consist of 300 lbs. superphosphate, supplying 48 lbs. phosphoric acid, besides sulphuric acid and lime, and 150 lbs. muriate of potash, supplying 75 lbs. actual potash. "Nitrogen mixture"= Nitrogen of soda, sulphate of ammonia, and dried blood, in equal parts. The pecuniary results, gain or loss, from use of nitrogen are estimated by assuming a bushel of corn with its stalks to be worth 80 cents.

Yields per acre in bushels with no manure and with "mixed minerals."

Number of experiment.	CORN.									POTATOES.					
	No manure.				Mixed minerals.					No manure.			Mixed minerals.		
	0.	00.	000.	Average.	6.	6a.	6b.	16.	Average.	0	00.	Average.	6.	16.	Average.
A. 1878	20.3	25.5	.....	22.9	39.0	.....	.....	.....	39.0	.....	.....	.....	.....	.....	.....
B. 1878	17.7	.....	.....	17.7	43.1	.....	.....	.....	43.1	.....	.....	.....	.....	.....	.....
D. 1878	11.3	7.0	10.1	9.5	70.3	.....	.....	.....	70.8	.....	.....	.....	.....	.....	.....
C. 1879	7.7	8.5	.....	8.1	42.0	.....	.....	36.5	69.3	46.0	56.0	51.0	82.0	126.0	104.0
E. 1879	39.5	44.6	44.5	42.9	.....	.....	.....	63.4	63.4	.....	.....	.....	.....	.....	.....
F. 1879	8.2	14.1	10.5	10.9	50.2	.....	.....	45.9	48.1	.....	.....	.....	.....	.....	.....
C. 1880	22.2	37.8	.....	30.0	52.8	.....	.....	52.3	27.6	78.0	62.0	70.0	114.0	158.0	136.0
G. 1880	11.4	7.9	.....	9.6	20.0	.....	.....	14.5	17.3	.....	.....	.....	.....	.....	.....
H. 1880	46.8	46.9	61.8	51.8	71.0	78.2	71.4	74.3	73.7	.....	.....	.....	.....	.....	.....
I. 1880	31.8	37.6	39.9	36.4	46.0	48.6	48.3	40.0	45.7	.....	.....	.....	.....	.....	.....
K. 1880	22.5	.....	25.0	23.8	22.5	30.0	27.5	33.3	28.3	.....	.....	.....	.....	.....	.....
C. 1881	7.3	12.4	.....	9.9	25.2	.....	.....	31.8	28.5	44.0	60.0	52.0	74.0	90.0	82.0
I. 1881	.....	.....	.....	.....	.....	.....	.....	.....	.....	28.0	46.7	37.4	90.7	96.0	93.4
M. 1881	38.2	33.1	.....	35.7	34.5	33.4	35.7	33.4	34.3	12.8	11.7	12.3	13.9	40.5	27.2
O. 1881	10.3	.....	.....	10.3	34.6	37.7	28.6	.....	33.6	.....	.....	.....	.....	.....	.....
L. 1881	12.5	13.8	.....	13.2	13.8	16.3	.....	20.6	16.9	.....	.....	.....	.....	.....	.....
N. 1881	40.0	35.4	.....	37.7	52.0	16.0	48.3	40.9	46.8	.....	.....	.....	.....	.....	.....
P. 1881	16.3	16.5	.....	16.4	28.2	30.1	29.0	39.7	31.8	.....	.....	.....	.....	.....	.....
Q. 1881	44.6	31.6	.....	38.1	58.9	56.7	51.1	57.2	56.0	.....	.....	.....	.....	.....	.....
	.....	.....	.....	23.6	.....	.....	.....	.....	48.0	.....	.....	44.5	.....	.....	88.5

TABLE XIII, PART II.—PECUNIARY RESULTS.

[Gain, +; Loss, —.]

EXPERIMENTS WITH CORN.

Cost of fertilizers:																
Whole	$14 25	$19 87½	$25 50	$9 37½	$18 75	$28 12½	$9 37½	$18 75	$28 12½	$13 87½	$19 12½	$24 37½	$18 75	$18 75	$19 32
Nitrogen	5 62½	11 25	16 87½	5 06½	10 12½	15 18½	5 06½	10 12½	15 18½	5 25	10 50	15 75	10 12½	10 12½	10 69½
Average of 3 experiments in 1878	+0 30	—6 21	—10 24							—0 37	—3 06	—7 88	—3 68	—5 65	—4 54
Average of 3 experiments in 1879	—3 47	—11 17	—18 80							—2 05	—12 26	—14 15	—3 41	—5 96	—5 65
Average of 5 experiments in 1880	+1 97	—0 37	+5 67							—2 29	—1 70	—1 02	—5 04	—2 12	—5 10
Average of 5 experiments in 1881	—4 01	—8 53	—12 47	—3 86	—5 56	—11 18	—3 03	—7 08	—11 34	—3 25	—8 18	—13 67	—16 04	—8 68	—12 13
Average of 5 experiments in 1878–'80	—1 03	—6 61	—11 75	—3 86	—5 56	—11 18	—3 03	—7 08	—11 34	—1 97	—6 26	—9 99	—7 32	—5 56	—6 85

EXPERIMENTS WITH POTATOES.

1 experiment in 1879	+3 38	—2 55	—7 87							+21 35	+2 70	—0 15	+9 08	+10 28	—5 89
1 experiment in 1880	+17 18	+41 55	+1 13							—17 25	—6 90	—14 65	+0 66	+0 08	—9 50
1 experiment in 1881	—11 30	—4 47	—16 15	—1 22	—12 38	—5 34	—17 92	—13 96	—16 44	—12 99	—10 14	—4 29	—1 10	—5 42	—4 13
1 experiment in 1879–'81	—10 82	—13 29	—9 73	—1 22	—12 38	—5 34	—17 92	—13 96	—16 44	—7 77	—4 02	—1 53	—2 38	—2 72	—2 71

TABLE XIII, PART III.—INCREASE OR DECREASE IN YIELD PER ACRE WITH NITROGEN.

[Estimated by subtracting yield with mineral fertilizers from yield with same plus nitrogenous fertilizers.*]

[Decrease indicated by —.]

EXPERIMENTS WITH CORN.

Number of plot.		7.	8.	9.							10.	11.	12.	13.	14.	15.
Nitrogen compounds added to mixed minerals.	Kinds.	Nitrate of soda.			Sulphate of ammonia.			Dried blood.			Nitrogen mixture.			Sulphate of ammonia.	Dried blood.	Peruvian guano.
	Pounds per acre.	150	300	450	.....	.....	.....	.....	.....	.....	150	300	450	225	450	.....
Nitrogen in above.	Pounds per acre.	24	48	72	.....	.....	.....	.....	.....	.....	24	48	72	48	48	48
	Number of experiment.	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
A.	1878	0.8	4.9	12.6	.....	.....	.....	.....	.....	.....	9.4	6.5	2.1	—3.1	5 3	9.1
B.	1878	8.7	4.6	4.3	.....	.....	.....	.....	.....	.....	7.0	7.7	13.4	15.1	12.2	6.8
D.	1878	13.7	9.4	8.1	.....	.....	.....	.....	.....	.....	1.8	13.6	14.3	11.9	—0.7	7.2
C.	1879	3.7	4.8	0.2	.....	.....	.....	.....	.....	.....	4.7	5.2	—0.2	3.7	4.2	2.0
E.	1879	—2.5	—2.0	—4.8	.....	.....	.....	.....	.....	.....	10.3	.....	11.8	24.6	—0.5	8.2
F.	1879	—9.4	—2.6	—2.7	.....	.....	.....	.....	.....	.....	—3.0	—9.6	—5.6	—3.1	11.9	8.7
C.	1880	—2.8	1.2	3.4	.....	.....	.....	.....	.....	.....	—5.4	—3.8	—1.7	—1.1	—0.3	—2.2
G.	1880	.....	.....	.....	.....	.....	.....	.....	.....	.....	—0.8	2.0	—1.1	4.9	8.7	—1.4
H.	1880	—1.0	—4.3	—10.1	.....	.....	.....	.....	.....	.....	—0.7	0.2	2.4	—2.1	6.0	3.7
I.	1880	11.5	15.1	11.4	.....	.....	.....	.....	.....	.....	9.9	17.9	19.8	9.0	10.2	11.5
K.	1880	30.3	42.2	51.3	.....	.....	.....	.....	.....	.....	15.0	38.7	52.5	15.0	29.6	23.4
C.	1881	3.6	—2.6	—6.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
L.	1881	9.5	27.9	42.9	12.2	26.2	32.0	8.2	13.2	20.0	.....	.....	.....	.....	.....	.....
M.	1881	2.8	—1.5	—0.3	2.7	3.9	—1.6	—1.6	—0.1	.....	.....	.....	.....	.....	.....	.....
N.	1881	—2.9	—3.3	1.4	—4.3	—4.9	—7.2	—3.2	—1.5	.....	.....	.....	.....	.....	.....	.....
O.	1881	—0.6	1.1	6.8	1.7	2.6	1.7	6.8	8.4	10.4	.....	.....	.....	.....	.....	.....
P.	1881	0.8	4.6	1.4	—2.3	1.3	3.5	8.7	1.8	—4.4	.....	.....	.....	.....	.....	.....
Q.	1881	—0.1	—2.2	—7.6	—0.9	5.0	—0.7	—1:7	—2.5	4.2	.....	.....	.....	.....	.....	.....
Ave. of exp't, 1881		1.9	3.4	5.5	1.5	5.7	5.0	2.2	2.9	4.8	2 5	2.9	2.6	—7.4	1.8	—1.8
Ave. of 5 exp'ts, 1880		9.5	13.6	14.1	.....	.....	.....	.....	.....	.....	3.7	11.0	14.4	5.1	10.0	7.0
Ave. of 3 exp'ts, 1879		2.7	0.1	—2.4	.....	.....	.....	.....	.....	.....	4.0	—2.2	2.0	8.4	5.2	6.3
Ave. of 3 exp'ts, 1878		7.4	6.3	8.3	.....	.....	.....	.....	.....	.....	6.1	9.3	9.9	8.0	5.6	7.7
Ave. of 3 exp'ts, 1878–'81		5.4	5.6	6.4	1.5	5.7	5 0	2.2	2.9	4.8	4.1	5.3	7.2	3.5	5 7	4.3

C.	1879	15.0	23.0	15.0						46.0	22.0	26.0	32.0	34.0	8.0
C.	1880	33.0	33.0	30.0						—20.0	6.0	2.0	—18.0	0.0	—4.0
C.	1881	26.0	22.0	15.0						32.0	26.0	32.0	12.0	20.0	12.0
I.	1881	34.0	46.3	26.0						28.7	42.7	34.7	25.3	31.7	37.3
M.	1881	24.7	16.3	—38.4	6.4	37.5	34.2	—18.1	—6.4	—2.1					
Ave. of exp't, 1881.		28.2	26.2	1.2	6.4	37.5	34.2	—18.1	—6.4	—2.1	30.4	34.4	33.4	18.7	25.9	24.7
Ave. of exp'ts, 1879–'80		26.5	35.6	22.5							13.0	14.0	14.0	7.0	17.0	2.0
Ave. of exp'ts, 1879–'81		27.4	49.9	11.9							21.7	24.2	28.7	12.9	21.4	13.3

*In making these calculations for Experiments C, E, F, and G, the yields on Plots 7, 8, and 9, Group I, were compared with that of Mixed Minerals No. 6, the yields of 13, 14, and 15, Group III with Mixed Minerals No 16; and those of Plots 10, 11, and 12, Group II, with the average of Nos. 6 and 16. But in Experiments H, I, and K, each group had a "mixed minerals" plot on each side; accordingly the yields of the first plots of each group were compared with that on the adjoining "mixed minerals" plot, and the middle one with the average of the two "mixed minerals" plots.

DETAILS OF SPECIAL NITROGEN EXPERIMENTS.

OBSERVATIONS REGARDING SOIL, WEATHER, CULTURE, CHARACTER OF PRODUCE, AND OTHER DETAILS.

As shown by the reports of individual experiments, of which examples have been given elsewhere, more or less extensive observations have been made and recorded concerning the circumstances and conditions of the experiments and the character of the results. A faithful statement of these observations, following as nearly as possible the language of the experimenters, will be valuable: to the experimenters, to show what their fellow-workers have done, and how; to other farmers who, in applying the results to their practice, will find profit in comparing the experimenters' circumstances with their own; to help, in general, to juster criticizing and valuation of the experiments, interpretation of the results, and improvement of plans and methods; and, finally, and most of all, to show what good work farmers can do in applying the methods of scientific investigation to the discovery of the principles on which their practice should be based.

The following details of the reports have been transcribed under my direction, with only such alterations as accuracy allows and omissions as the permitted space demands. Only the details of the nitrogen experiments are given here, however. Those of the general experiments, though most interesting and valuable, are necessarily omitted. Some of the principal facts, however, are included in Tables IV–X.

NITROGEN EXPERIMENTS.

A. 1878. PROF. J. R. FARRINGTON, Maine State College of Agriculture and Mechanic Arts, Orono, Me.—Experiment with *Corn*.

SOIL.—*Situation*, nearly level, but with a slight swell running across the middle of the field, draining the surface water off each way in the direction of the length of the rows. KIND, heavy clay, *dry or wet*, moist, not underdrained. *Texture*, compact. PREVIOUS TREATMENT AND YIELD.—In meadow (mowing) for ten years. In 1873–'74 plots running at right angles to and nearly across the plots of the present experiment received a manuring of mineral and nitrogenous fertilizers. If any effect from those fertilizers remained it would be felt alike by all of the present plots. TILLAGE, &C.—The land was plowed six inches deep ten days before it was planted; was prepared for planting by thoroughly pulverizing with Randall's harrow; measured rows marked with a marker drawn by hand. Fertilizers mixed with sawdust, carefully distributed, worked into the soil, and seed dropped and covered with a hoe. OTHER REMARKS.—The soil of the field has a remarkable uniformity of appearance.

B. 1878. W. I. BARTHOLOMEW, Pomfret (P. O. address, Putnam), Conn.—Experiment with *Corn*.

SOIL.—*Situation*, summit of hill. *Kind*, black, clayey loam, yellow below; at 1½ or 2 feet becomes a stony, compact clay. *Texture*, loose surface if not trodden when wet. *Dry or wet*, variable with the season. *Depth of surface soil*, 6 or 8 inches. *Subsoil*, hard and compact. PREVIOUS TREATMENT AND YIELD.—Never received much manure previous to 1875. In grass in 1875–'77, crop about one ton. FERTILIZERS, HOW APPLIED.—Scattered in and around the hills before dropping the corn. TILLAGE.—Hoed twice, and corn thinned to four stalks in hill at second hoeing. A small part of Nos. 10 and 11 were replanted, and corn did not get so large a growth in those plots. WEATHER.—Favorable; corn came up well, and stood remarkably well through the season. OTHER REMARKS.—After drying one month the ears showed a shrinkage of about 5 per cent. in weight. 70 pounds of ears as harvested yielded, after drying one month, 55¼ pounds of shelled corn. One bushel dry shelled corn weighed 60$\frac{5}{16}$ pounds,

PLOTS.—Size, $\frac{1}{10}$ acre. *Rows*, 3½ feet apart. *Kind of corn*, white cap corn. *Planted*, May 16—20. *Harvested*, September 30–October 10.

C. 1879. 1880, and 1881. Also by Mr. BARTHOLEMEW.—Experiments with *Corn* and *Potatoes*, side by side, as per description of experiment of 1878.

The experiment was on a part of the same field as that of 1878, and the other details were similar.

C. 1879. WEATHER.—In 1879, cold, wet, and unfavorable to corn throughout; better for potatoes: except in spring potatoes came up slowly. Severe storms in July and August. Frost killed corn (September 25) before maturity. Potatoes were planted, like the corn, in hills 3½ by 3½ feet, which gives not more than half the hills usually made per acre for this crop, but were so planted for uniformity, and to allow cultivating both ways. No doubt there would have been nearly double the number of bushels if they had been planted as thick as usual. The hills on the best plots were so full of fine, smooth potatoes as to excite great approbation among those who saw them, and not as much worm-eaten as was common here this season.

C. 1880. WEATHER.—Good for corn, but too hot and dry for potatoes, although my crop was very good when compared with most of my neighbors. Fertilizers applied in the drill. These experiments with potatoes are perhaps the most unsatisfactory to me of any that I have reported. In some of the plots the seed appeared to be injured by the fertilizers and were replanted, but this was of little result. Accidents prevented uniformity in hoeing, which appeared to affect the crop; and also trusting slightly to others in harvesting makes some of the figures a little uncertain.

C. 1881. WEATHER.—*May*, latter part of month very warm. *June*, cold and wet. Severe cold storm before crops came up. *July*, frequent and severe showers. Hard hailstorm July 4th. *August*, cloudy. Unfavorable for both corn and potatoes in this section. The crops of both were light. FERTILIZERS APPLIED as in former experiments, but a severe storm coming on soon after the corn and potatoes came up, dissolved the fertilizers and appeared to injure the young plants slightly, especially where the quantity was largest. *Planting and tillage* as heretofore. OTHER REMARKS.—A severe hailstorm July 4th broke down and battered the young plants, both of corn and potatoes so badly that I almost despaired of a crop worth reporting, and was advised to plow it up and sow buckwheat instead, but the potatoes finally made a fair growth, although the yield was too small. The corn was perhaps the most injured, and, as the season was bad, was very poor. Although the crops were small in consequence of the hail, &c., perhaps the relative effects of the fertilizers were as manifest as in a good season. The same marked difference existed that has characterized the use of different fertilizers with me from the beginning of my experimenting, several years ago. The first year's story is repeated each successive year, only as modified by the seasons. Most likely the storm about the 1st of June, which completely saturated the ground, gave some of the plots which were lightly fertilized, or not at all, the benefit of fertilizers of adjacent plots, especially the 00 plot. The ground descends from the larger numbered plots toward the smaller numbered ones, and consequently the fertilizers tended in a flood in that direction.

D. 1878. CHESTER SAYE, Middletown, Conn.—Experiment with *Corn*.

SOIL.—*Situation*, upland, sloping to the east. *Kind*, loam, some cobble-stones *Texture*, loose, not drained, compact after rains. *Depth of surface-soil*, about 6 inches. *Subsoil*, yellow, with cobble-stones, hard in dry weather. *Other remarks*, the land "has been faithfully neglected." PREVIOUS TREATMENT AND YIELD.—No manure put on for three years previous to 1875. No manure in 1875–'77, crop, 1¼, 1 and ¾ tons of hay per acre. WEATHER.—*April*, rain, 5th, 10th, 11th, 21st, 23d, 25th, 28th, 29th. *May* rain, 5th, 9th, 20th, 21st, 25th, 30th, 31st. *June*, rain, 3d, 10th, 11th, 12th, 13th, 17th, 18th 22d, 24th, 27th. *July*, rain, 4th, 9th, 10th, 12th, 21st, 27th, 30th. *August*, rain, 1st, 2d

4th, 6th, 9th, 16th, 20th, 21st, 25th. FERTILIZERS, HOW APPLIED.—Broadcast and cultivated in. TILLAGE.—Cultivated both ways twice and hoed. OTHER REMARKS.—The birds pulled the corn badly, and although it was replanted there were some missing hills. Many hills in each plot had a less number of stalks than was intended. The number of hills in each plot containing one or more stalks was counted, and the yield per acre estimated as if the missing hills had yielded corn equal to those hills that grew. PLOTS.—454 feet × 7½ feet = 12 1/12 square rods. (Fertilizers applied at rate of one-tenth acre for each bag.) *Rows*, 3½ feet apart. *Hills*, 3½ feet apart. *Planted*, May 29. *Harvested*, October 25 and 26. *Pounds allowed for a bushel of produce*, 70 of good ears, 140 of poor ears.

E. 1879. Experiment with corn; also by Mr. SAYE, but on another field of the same farm.

SOIL.—Upland northern slope, gravelly loam, thin turf, compact, dry. Depth of surface soil 5 inches. *Subsoil*, yellow and heavy. PREVIOUS TREATMENT AND YIELD.—No manure, one-half ton hay in 1876 and '77; no manure, three-fourths ton hay '78. FERTILIZERS, HOW APPLIED.—Sowed broadcast on each row, except unmanured rows, which were 3 feet 9 inches wide. Plots, 440 feet by 3 feet 9 inches = 6 1/16 square rods. *Crop*, corn. *Rows*, 3 feet 9 inches apart. *Hills*, 3 feet 9 inches. *Planted*, May 25. *Harvested*, first week in November, 70 pounds in ear per bushel. Tillage. OTHER REMARKS.—This report includes only three unmanured rows. For 20 rows each alternate row was without manure, so that the first 10 rows with manure had 10 rows without manure between them, and had I saved rows enough for the whole 16 rows of the experiment, I should have separated every row where manure was put by or with a row where no manure was put.

F. 1879. JOHN B. MEAD, Randolph, Orange County, Vermont.—Experiment with *Corn*.

SOIL.—Base of hill southeast slope. *Kind*, dark loam, with some clay, light when dry. *Dry or wet*, variable with the season, dry enough for corn. *Depth*, 4–8 inches. *Subsoil*, somewhat hard and compact. PREVIOUS TREATMENT AND YIELD.—Run out meadow with — ton to half a ton of hay per acre. Plowed in 1878 and sowed to oats with no manure; yield, 25 bushels. WEATHER.—Cold and backward in spring and early summer; worst season for corn in this section for 20 years. SIZE OF PLOTS.—Eight square rods. *Planted*. May 26. *Harvested*, October 8. FERTILIZERS APPLIED broadcast by hand, being careful that each plot received its own and no more. PLANTING AND TILLAGE.—Thoroughly worked with harrow before application of fertilizers; seed planted with horse planter in hills about 2 feet apart. Cultivated twice and kept free from weeds by hand-hoeing. OTHER REMARKS.—The labor was less than usual in corn raising. The season being unfavorable, the crop was small, but the experiment has taught me much that is valuable to me, and if it will repeat itself, as I think it will repeat itself, it will be worth thousands of dollars upon my farm.

G. 1880. PROF. W. H. JORDAN, Maine Agricultural and Mechanical College, Orono, Me.—Experiment with *Corn*.

SOIL.—Upland quite level. *Kind*, clayey loam, with a strip across somewhat lighter, with small stones very similar to A. 1878. *Dry or wet*, medium. PREVIOUS TREATMENT.—Pasture. WEATHER.—A very dry season, indeed, until about the last of August. The drought injured the crop very much. FERTILIZERS, HOW APPLIED.—In hill, with thorough mixing with soil. TILLAGE.—The land was plowed in the spring just before planting and pulverized with a Randall harrow. The land had also been plowed the fall previous. Thorough tillage was kept up during growing season.

H. 1880. EDWARD HICKS, Old Westbury, Queens County, New York.—Experiment with *Corn*.

SOIL.—Level, sandy loam, dark color, light and loose. *Dry or wet.* Dry. *Depth of surface soil,* 6–8 inches. *Subsoil,* yellow loam. WEATHER.—Dry, though very favorable; crop throughout the island unusually heavy. The drought had no perceptible effect upon the growth of the corn. FERTILIZERS, HOW APPLIED.—The ground was laced out 3 feet 9 inches apart, with a light lace and the fertilizer for each plot was put in a pail and the pail filled with dry earth and thoroughly mixed with the fertilizer; this gave an even quantity to apply to each plot on the lace marks. The corn planter opening a furrow through the lace marks, stirred the fertilizer and soil together. TILLAGE.—The corn ground was smoothed with a plank drag and harrowed twice after the corn was up, then cultivated twice, leaving the ground perfectly level. It was hoed and thinned out at the same time, leaving the plants 10 to 12 inches apart. OTHER REMARKS.—The corn was not husked till November 24–30, and as some of the stalks were blown down and wet we did not weigh the stalks. The stalks appeared to be very uniform throughout the whole of the plots. Since reading your remarks in the American Agriculturist about the length of plant roots, I think that a vacant plot should be between every fertilized plot. My unmanured plots were too narrow. I do not think they would have yielded near as well had they been, say, four rows wide, and to take account of only the two middle rows. The second and third plot got mixed in cutting up the corn on one end of the plots, and the figures for them are not as exact, having to estimate from the other end of the two plots. No width was allowed except width of the rows 3 feet 9 inches.

P. 1881. HICKS, as above.—Experiment with *Corn*.

SOIL.—Dead level. *Kind,* sandy loam, light. *Dry or wet,* dry. *Depth of surface soil,* 7-9 inches. *Subsoil,* yellow loam, 4-8 inches, then gravel. PREVIOUS TREATMENT AND YIELD.—Corn, succeeded by potatoes and oats; then winter wheat and rye, seeded with timothy and clover; mowed three years, then pasture one or two years. WEATHER.—Planted 18th to 20th of May; ground in good, warm condition. *June,* favorable; little too cool. *July,* dry. *August,* very dry. Very unfavorable the last half of the growth of the crop. FERTILIZERS, HOW APPLIED.—Broadcast on six rows, so that the outside rows did not have any fertilizer on the outside of the row. Each bag was mixed thoroughly with sifted, damp earth, to bring the quantity of each bag to two large parts full. A pailful was applied to each three rows; the damp earth helped to prevent the wind from blowing the dry fertilizers. TILLAGE.—Albany corn, planted with a weighted wheel to follow and press the earth firmly upon the seed. Used a smoothing harrow as soon as the corn was six inches high. Cultivated, then hoed and thinned out to one plant to 10 to 12 inches. Worked out the corn twice with riding Disc harrow; this hilled up the corn perhaps too much. OTHER REMARKS.—By referring to diagram of unmanured plots you will observe that the north end of the plots yield very much more than the others. You will also observe that plot 6*c*, mixed minerals, is much larger in yield than the other plots, 6, 6*a*, 6*b*, mixed minerals, which are quite uniform. I attribute it to either having had potatoes planted on the north side of the field adjoining the fence the last time it had potatoes and oats, about seven years ago, or to snow-banks lying there, or both; it is where we had potatoes, I have no doubt, as they were manured very heavily. Now this makes a want of uniformity in the soil, and plots Nos. 1 and 6 are not a correct yield from the fertilizer applied. Perhaps plots Nos. 2 and 15 are also a little affected by it. I take the average of unmanured plots on the east side for No. 0, and on the west side for No. 00.

I. 1880. CHARLES FAIRCHILD, Middletown, Conn.—Experiment with *Corn*.

SOIL.—Upland level, sandy loam, light, and loose. *Dry or wet,* dry, decidedly. *Depth of surface soil,* about 6 inches. *Subsoil,* sandy and gravelly. PREVIOUS TREAT-

MENT AND YIELD.—Previous to 1877 the field was an old pasture, thoroughly run out and already infested with bushes; it had not been plowed for twenty years or more. WEATHER.—*May*, very dry; severe drouth. *June*, very dry, but some showers. *July*, considerable wet weather early in the month. *August*, fine growing weather; on the whole very favorable for corn. FERTILIZERS, HOW APPLIED.—Sowed broadcast and harrowed in. Between each two plots was left an unmanured strip two feet wide; that is, the fertilizers were spread so as to cover 8½ feet of the 10½ feet of the width of the plot, thus leaving a foot on each side of each plot, or a strip two feet wide between each two plots unmanured. TILLAGE.—Planted 4 kernels in each hill; hills 3½ feet apart each way; cultivated both ways four times; not hand-hoed. OTHER REMARKS.—Neither nitrogen nor potash alone seemed to help much, but with other materials each increased the yield. In other cases muriate of potash alone has proved very efficient.

I. 1881.—Experiment with *Corn*.

SOIL.—Upland, level sandy loam, light. *Dry or wet*, dry. *Depth of surface soil*, 5-6 inches. *Subsoil*, sandy and gravelly. PREVIOUS TREATMENT AND YIELD. Pasture. WEATHER.—Favorable. FERTILIZERS, HOW APPLIED.—Broadcast.

I. 1881.—Experiment with potatoes.

SOIL.—Similar to I, 1881, with corn. WEATHER.—*May*, warm. *June*, cold and wet. *July*, warm and dry. *August*, warm and dry. FERTILIZERS, HOW APPLIED.—Broadcast. TILLAGE.—Planted in drills 3½ feet apart, 2 feet in row. The potatoes were cut in small pieces, with two eyes in a piece, and one piece in a place. Hoed by hand once, cultivated with horse hoe three times.

K. 1880. WILLIAM C. NEWTON, Durham, Conn.—Experiment with *Corn*.

SOIL.—Upland slope to northeast, dark loam, few stones. *Dry or wet*, moist. *Depth of surface soil*, 5–6 inch. *Subsoil*, yellow loam, some stones. PREVIOUS TREATMENT AND YIELD.—1876, corn with a hundred pounds guano per acre, yielded about 150 bushels of ears per acre. 1875, corn, 1 ton of fish scrap per acre yielded about 125 bushels ears per acre. 1874. 1 ton of fish scrap per acre yielded about 110 bushels per acre. I think in 1876 there were some German potash salts applied, do not know the quantity. WEATHER.—Season favorable for corn. FERTILIZERS, HOW APPLIED.—Special nitrogen set half size, applied broadcast. TILLAGE.—Hand hoed once, cultivated twice, which kept the ground free from weeds. Plowed between the different plots in order to cut the roots and prevent them feeding on the adjoining plot.

L. 1881. Also by Mr. NEWTON. Adjoining portion of the same field as the experiment of 1880.

M. 1881. Prof. C. L. INGERSOLL, La Fayette, Ind.—Experiment with *Corn*.

SOIL.—First level or bluff 100 feet above level of Wabash River; black soil, similar to prairies, but with less organic matter; finely divided and sticky when wet; bakes when dry. *Dry or wet*, naturally dry; well drained. *Depth of surface soil* 8 to 24 inches. *Subsoil*, gravel 30 to 90 feet deep. Best suited for corn and wheat. Corn varies from 30 to 40 bushels per acre; wheat 18 to 30 per acre. PREVIOUS TREATMENT AND YIELD.—Treatment not known previous to 1878; supposed in grass, either meadow or pasture, for four years at least. 1878, pasture. 1879, pasture. 1880, corn; 38.7 bushels per acre. WEATHER.—*April*, cold first half, warm second half. Rather dry; 2.25 in. rain-fall. Frost to the 17th. *May*, warm except first week; rain-fall, 3.82 inches. Drought from May 15 to June 5. *June*, warm and wet from 5 to 20. Rain-fall, 7.16 inches. No

ain except twice from July 22 to September 2. Rain-fall 2.5 inches, in 10 days; ot and dry. Temperature 103° for two days. *August*, very hot and dry; temperature 00° or over for 10 days. Highest temperature, 107°. Rain-fall, 0.47 inch. Very unavorable season for the crop. FERTILIZERS, HOW APPLIED.—Applied by hand after mixing with about twice its bulk of earth. Distributed a foot on either side of the row. TILLAGE AND PLANTING. Planted by hand in hills 4 feet 2 inches apart each way. In rows for cultivation in two directions. Tillage by horse. OTHER REMARKS.—Land plowed May 9; harrowed once, May 11, with smoothing harrow. Planted May 12, 6 and 7 grains in a hill. Fertilizers applied May 14; cultivated five times. No unmanured strips between plots, except in Nos. 1 and 20, 0 and 00 of corn plan. Scattering weeds hoed out July 9; corn cut *October* 1 and 3. Husked *October* 8 and weighed *October* 15.

M. 1881, *Potatoes*. Similar to corn, 1881, in respect to soil, weather, and application of fertilizers. Planted by hand in hills 1 foot 4 inches apart in rows for cultivation in one direction. *Tillage* by horse and by hand. Potatoes cut in about six pieces and two dropped in a place. Rows 33 inches apart. Cultivation only north and south. OTHER REMARKS.—Land plowed April 22; harrowed once with smoothing harrow. Planted April 23; cultivated five times. Hoed *June* 11 and *May* 18. No unmanured plots except 0 and 00. Five feet width between these and the manured plots. Potatoes dug and weighed September 24. Unfortunately part of our seed was mixed, and hence the results are not as accurate as we would wish.

N. 1881. C. E. THORNE, farm manager, Ohio State University, Columbus, Ohio.—Experiment with *Corn*.

SOIL.—Level upland, clayey loam, dark, medium amount of vegetable matter. "Drift" formation from Huron shale moderately compact, thoroughly drained in *April* and *May*. *Dry or wet*, wet before drainage. *Depth of surface soil*, owing to the formation the division between the surface soil and subsoil is not distinctly marked. The plow has been lowered to 12 inches without increase of crop. *Subsoil*, about 18 inches below surface of bowlder clay; very retentive. PREVIOUS TREATMENT AND YIELD.—1876 sowed to grass, but it failed to take; 1877 corn. WEATHER.—*April*, cold and wet; during the first half a heavy snow covered the ground; closed dry. *May* dry. *June* dry; one good rain about the 10th. *July* dry; light rains latter part of month. *August* dry. Season so dry as to cause a loss of 50 per cent. in yield. FERTILIZERS, HOW APPLIED.—The fertilizers were spread by hand in strips 2½ to 3 feet wide, having the corn row as the center of the strip. The rows were of such length that three rows occupied $\frac{1}{10}$ acre of land. The stable manure was spread in a continuous strip, occupying the whole width of the plot. TILLAGE.—The corn was planted (east and west) with a two-horse corn-planter, on the 26th of May. It was cultivated four times during the season with a two-horse cultivator.

O. 1881. J. W. PIERCE, West Millbury, Mass.—Experiment with *Corn*.

SOIL.—Upland, nearly level, except southwest corner, which is on hill-side; clay and gravelly loam; color light, with yellow subsoil, light and mellow in texture. *Dry or wet*, dry, but does not suffer from drought. *Depth of surface soil*, from 6 to 7 inches. *Subsoil*, gravelly, with some clay. PREVIOUS TREATMENT AND YIELD.—Most of it manured and planted with corn in 1875; oats, without manure, in 1876; clover, without manure, in 1877. WEATHER.—*April*, wet. *May*, first half warm, last half wet and cold. *June*, wet and cold. *July* dry, but cloudy and cold. *August*, first part cold, last part warm; and *September*, warm and dry; on the whole cold and unfavorable for corn. FERTILIZERS, HOW APPLIED.—Sown broadcast and harrowed in with wheel harrow. The small messes were mixed with enough damp sawdust to make the bulk of each bag about the same, and sown thicker in center of plots than at sides. In planting the ground was marked both ways $3\frac{3}{10}$ feet apart, or 25 hills to the square rod.

TILLAGE. It was cultivated three times each way; hoed once, and horse hoed both ways when just tasseling, August 8. OTHER REMARKS.—These plots have a southwest aspect.

Q. 1881. SAMUEL JOHNSON, Agricultural College, Lansing, Mich.—Experiment with *Corn.*

SOIL.—Level upland, sandy loam, except about ⅛ of each plot at the east end, which is clayey loam. *Texture*, light and loose; drained. *Dry or wet*, dry, but withstands drought well. *Depth of surface soil*, about 8 inches. *Subsoil*, mostly sandy or gravelly; clay at east end of plots. PREVIOUS TREATMENT AND YIELD.—In 1874 corn; 1875 roots, with good dressing of barn-yard manure; 1876 oats; 1876–'77 wheat and seeded to clover. WEATHER.—*April*, cold and wet. *May*, favorable. *June*, rains on 8th and 12th; 15th to 23d, cold, with some showers; 27th rain; too cold during month for corn. *July*, rain on 7th; latter part too cold; entirely too dry. *August*, rain 5th and 18th; warm but too dry. Unfavorable on the whole. FERTILIZERS, HOW APPLIED.—By hand, then thoroughly harrowed into the soil with a Thomas smoothing harrow before planting. Each plot consisted of a single row, which was unmanured 10 feet on either side, making the manured strip 4 feet wide. An unmanured strip 4 feet wide was left between each plot of corn. The corn was planted in hills 4 feet apart in the row; the rows were 8 feet apart; that is, every other row was left vacant. TILLAGE.—The crop was cultivated five times. A few weeds were pulled late in the season. OTHER REMARKS.—The shelled corn is estimated from average samples of the good corn, which were thoroughly dried and shelled January 9, 1882. The shelled corn averaged nearly 71 per cent. of the fresh corn in the ear, owing to wet weather previous to husking; neither corn nor fodder was very dry when husked.

S. 1881. Prof. W. C. STUBBS, Auburn, Lee County, Ala.—Experiment with *Cotton.*

SOIL.—Level upland, sandy, with small quantity of vegetable matter; light, well drained. *Dry or wet*, very dry. *Depth of surface*, 4 to 6 inches. *Subsoil*, reddish yellow clay. PREVIOUS TREATMENT AND YIELD.—It had been pastured. Bermuda grass had grown up here and there in patches, but was nearly all removed by hand, and hoed before experiment. WEATHER.—*May*, planted; seasonable. *June*, seasonable. *July*, long drought, but on account of late planting did but little damage. *August*, showery and seasonable. On whole, rather unfavorable season. FERTILIZERS, HOW APPLIED.—In drill, and bedded on them. Three rows 3 feet wide to each experiment. Each parcel of fertilizer weighed into three equal parts. Mixed evenly with dry earth, and applied as carefully as a skilled hand could do it. TILLAGE AND PLANTING.—Planted with ordinary cotton-planter. Chopped to a stand, and cultivated with cultivator sweep and hiller. OTHER REMARKS.—Only a fair stand was obtained. Cotton planted too late, on account of detention of fertilizers "in transitu" from New York.

S. 1881. J. M. MANNING, Raynham, Taunton, Bristol County, Mass.—Experiment with *Clover.*

SOIL.—Upland, with gentle slope to the east, southeast, and northeast; sandy loam; some gravel and small stones on south side, loose; lower corner northeast more compact. *Dry or wet*, medium. *Depth of surface*, 6 or 7 inches. *Subsoil*, yellow sand. PREVIOUS TREATMENT AND YIELD.—A small crop of grass taken off each year for several years, and no manure applied. WEATHER.—*April*, wet. *May*, wet; third week very rainy. *June*, wet; rain on the 2d, 3d, 7th, 8th, 10th, 19th, 26th, and 30th. On the 28th three heavy showers. *July*, light shower on the 2d, 4th, and 8th; heavy shower on the 21st; last week cloudy and rainy. *August*, dry; last part hot. The first part of the season, May and June, very hot, which occasioned delay in seeding. July fa-

vorable; August and first half of September too dry. FERTILIZERS, HOW APPLIED.—Bushed in the seed, driving lengthwise of the plots, and rolled the ground. Mowed the grass with a machine September 16, driving directly across the plots, north and south. Raked each plot separately, by setting up five stakes in a line between two plots, and moving each stake three paces or 9 feet as we came to it in raking. I. Spread the fertilizer uniformly, leaving a strip three-fourths of a foot wide between each plot unmanured; harrowed the ground lengthwise of the plots. These extended east and west, at right angles with those in the experiments of the previous years. III. The very heavy showers on the 28th of June, three days after sowing the seed, washed some of it away, and into hollow places, and probably some of the fertilizer with it. OTHER DETAILS.—At intervals on plot No. 5, about one-third of its area in all, nothing came up, scarcely a weed. The ground was nearly level, yet possibly the bush dragged the seed into the hollow places. I have added to the actual weight of hay on this plot one-half its weight, to make up for the vacant places. The clover came up quite uniformly on the other plots, though it did not make a large growth, on account of the late sowing and dry weather in August. Weeds were thrown out. Considerable fine grass came up of its own accord among the clover. September 21 carted the hay into the barn and weighed it. The hay was dry and of good quality for producing milk.

DEPARTMENT OF AGRICULTURE, COMMISSIONER'S OFFICE.

The following paper, prepared for this country and read before the American Association for the Advancement of Science, in August, 1882, is considered an important addition to the views of Professor Atwater contained in this volume.

GEO. B. LORING,
Commissioner.

DETERMINATIONS OF NITROGEN IN THE SOILS OF SOME OF THE EXPERIMENTAL FIELDS AT ROTHAMSTED, AND THE BEARING OF THE RESULTS ON THE QUESTION OF THE SOURCES OF THE NITROGEN OF OUR CROPS.

BY SIR JOHN BENNETT LAWES, BART. LL. D., F. R. S., F. C. S., AND JOSEPH HENRY GILBERT. PH. D., F. R. S., F. C. S., F. L. S.

It is just about a century since the question of the sources of the nitrogen of vegetation became a subject of experimental inquiry, and also of conflicting opinion. It is nearly half a century since Boussingault was led by a study of the chemistry of agricultural production to see the importance of determining the sources of the nitrogen periodically available to vegetation over a given area of land. Somewhat later, the Rothamsted experiments, now in their fortieth year, were commenced, and in their progress many facts have been elicited bearing upon the same subject. Still, almost from the date of Boussingault's first investigations, the question has been one of controversy, and at the present time very conflicting views are entertained respecting it.

For ourselves, we have pointed out how entirely inadequate is the amount of combined nitrogen coming down in the measurable aqueous deposits from the atmosphere to supply the nitrogen of the vegetation of a given area. Other possible supplies of combined nitrogen from the atmosphere have also been considered and pronounced inadequate. Again, the question whether or not plants assimilate the free or uncombined nitrogen of the atmosphere has been the subject of laborious experimental inquiry, and also of critical discussion, at Rothamsted. Finally, the question whether the stores of the soil itself are an important source of the nitrogen of our crops has frequently been considered.

It may at the outset be frankly admitted that so long as the facts of production alone are studied, without knowledge of, or reference to, the changes in the stock of the nitrogen in the soil, it would seem essential to assume that a large proportion of the nitrogen of crops growing without any direct supply of it by manure must be derived, in some way or other, from atmospheric sources. The assumption which is most

in favor with some prominent writers is, that whilst some plants derive most or all of their nitrogen from the stores of the soil itself, or from manure applied to it, others derive a large proportion from the free nitrogen of the atmosphere. We, on the other hand, whilst freely admitting that the facts of production are not conclusively explained thereby, have maintained that such collateral evidence as the determinations of nitrogen in our soils afford, is in favor of the supposition that the soil may be the source of the otherwise unexplained supply of nitrogen. This latter conclusion we have frequently stated in general terms, but we have not hitherto published the numerical results upon which it is based. Fairly enough, it has been objected that such an important conclusion cannot be accepted without the numerical evidence to support it. Further, erroneously interpreting our statements, calculations have been made to show that it is quite beyond the reach of present methods of determination of nitrogen in soils to afford results justifying the conclusions we have drawn. Since this subject of the sources of the nitrogen of our crops has been much discussed in America, it has been thought that it would not be inappropriate to answer the challenge by bringing forward some of the numerical evidence we have accumulated before this meeting of the American Association for the Advancement of Science, and to do this is the object of the present communication.

Before calling attention to the special results in question, it will be necessary, however, to convey a clear idea of the problem to be solved, by recapitulating some of the important facts which have been established as to the amount of nitrogen yielded over a given area by different crops. In his original inquiries Boussingault estimated the amounts of nitrogen supplied by manure and removed in the crops in ordinary agricultural practice. This mode of estimate is also the one generally adopted by others, and we have ourselves not neglected it. But it is obvious that the results of experiments in which different crops have been grown for very many years in succession on the same land, both separately and, in actual course of rotation, and both without nitrogenous manure and with known quantities of such manure, must afford very important data as to the amounts of nitrogen available to vegetation, from soil and atmosphere, over a given area. The Rothamsted field experiments are pre-eminently adapted to provide such data. Thus, wheat has now been grown for thirty-nine years in succession on the same land; barley for thirty-one years; wheat in alternation with fallow thirty-one years; beans for nearly thirty years; clover for many years; turnips, sugar-beet, or mangels nearly forty years: whilst experiments on the mixed herbage of grass-land have been continued for twenty-seven years, and on an actual course of rotation for thirty-five years. We have, from time to time, published what we may call the nitrogen statistics of the crops so grown; and we have compared these facts of production with what is known of the sources of nitrogen available to the crops.

YIELD OF NITROGEN IN DIFFERENT CROPS.

The following table (I) shows the yield of nitrogen per acre per annum in wheat, barley, root crops, beans, clover, and in ordinary rotation, in each case without any nitrogenous manure. It will be observed that only in the case of the root crops is the record brought down to a later date than 1875. Independently of the fact that the requisite nitrogen determinations are not yet completed for the subsequent period, it has been decided that owing to the number of very exceptionally unfavorable seasons for corn crops which have occurred since 1875, it would be fallacious to bring the results for those crops in the later seasons as illustrating the falling off of yield due to soil exhaustion.

TABLE I.—*Yield of nitrogen per acre, per annum, in various crops at Rothamsted, without nitrogenous manure.*

Crop, &c.	Condition of manuring, &c.		Duration of experiment.	Average nitrogen per acre per annum.
				Pounds.
Wheat	Unmanured		8 years, 1844–'51	25.2
			12 years, 1852–'63	22.6
			12 years, 1864–'75	15.9
			24 years, 1852–'75	19.3
			32 years, 1844–'75	20.7
	Complex mineral manure		12 years, 1852–'63	27.0
			12 years, 1864–'75	17.2
			24 years, 1852–'75	22.1
Barley	Unmanured		12 years, 1852–'63	22.0
			12 years, 1864–'75	14.6
			24 years, 1852–'75	18.3
	Complex mineral manure		12 years, 1852–'63	26.0
			12 years, 1864–'75	18.4
			24 years, 1852–'75	22.4
Root crops	Complex mineral manure	Turnips	8 years, 1845–'52	42.0
		(Barley)	3 years, 1853–'55	(24.3)
		Turnips	15 years, 1856–'70[1]	18.5
		Sugar beet	5 years, 1871–'75	13.1
		Mangles	5 years, 1876–'80	15.5
		Total	36 years, 1845–'80	25.2
Beans	Unmanured		12 years, 1817–'58	48.1
			12 years, 1859–'70[2]	14.6
			24 years, 1847–'70	31.3
	Complex mineral manure		12 years, 1847–'58	61.5
			12 years, 1859–'70[2]	29.4
			24 years, 1847–'70	45.5
Clover	Unmanured		22 years, 1849–'70[3]	30.5
	Complex mineral manure		22 years, 1849–'70[3]	30.6
Barley	Unmanured		1 year, 1873	37.3
Clover			1 year, 1873	151.3
Barley	Unmanured	After barley	1 year, 1874	30.1
		After clover	1 year, 1874	60.4
	Barley after clover more than after barley			30.3
Rotation 7 courses	1. Turnips 2. Barley 3. Clover or beans 4. Wheat	Unmanured	28 years, 1848–'75	36.0
		Superphosphate	28 years, 1847–'75	45.2

(1) Thirteen years' crop, two years failed. (2) Nine years' beans, one year wheat, two years' fallow. (3) 6 years' clover, 1 year wheat, 3 years' barley, 12 years' fallow.

YIELD OF NITROGEN IN WHEAT AND BARLEY.

The first series of results relate to the yield of nitrogen in wheat grown thirty-two years in succession on the land without manure. It is seen that over the first eight years the yield was 25.2 pounds of

nitrogen per acre per annum, over the next twelve years 22.6 pounds, and over the last twelve of the 32 years only 15.9. There has thus been a considerable reduction in the annual yield of nitrogen over each succeeding period; and for the third period of twelve years the average is less than two-thirds as much as for the first period of eight years.

Excluding the first eight years of the growth of wheat, the average annual yield of nitrogen over the next twenty-four years was 19.3 pounds per acre per annum; and the table shows that over the same twenty-four years, barley without manure yielded 18.3 pounds, and whilst with the wheat the decline in yield was from 22.6 pounds over the first twelve of the twenty-four years to 15.9 over the second twelve, it was with the barley from 22.0 to 14.6 pounds, or almost in the same proportion.

It might be objected that here the evidence is not conclusive that the falling off is due to the gradual reduction in the amount of nitrogen annually available from the soil. But the results with the two crops, where there is a liberal supply of mineral constituents every year, exclude the supposition that the decline is due to the exhaustion of mineral constituents. Thus, over the same twenty-four years, with a complex mineral manure, such as is very effective when there is artificial supply of nitrogen also, the yield of nitrogen in the wheat, falls off from 27.0 pounds per acre per annum over the first twelve years, to 17.2 pounds over the second twelve years; and that in the barley, over the same two periods, from 26.0 to 18.8 pounds. The similarity in the actual yield, and in the rate of decline of yield, of nitrogen over the same periods in these two closely allied crops, though growing in different fields, and with somewhat different previous manurial history, is very striking. The slightly higher yield in both cases with than without the mineral manure is doubtless due to more complete utilization of the previous accumulations within the soil, and not to increased assimilation from atmospheric sources.

YIELD OF NITROGEN IN ROOT CROPS.

We now come to the yield of nitrogen by plants of other natural families, and the first of such results relate to the so-called "root crops"—turnips of the natural order Cruciferæ, and sugar-beet, and mangel-wurzel of the order Chenopodiaceæ. The table records the results for thirty-six years in succession, 1845–1880; but it should be stated that during three of those years barley was interposed without any manure in order, as far as possible, to equalize the condition of the land before rearranging the manuring, and during two other years the turnips failed, and there was no crop. It should be further explained, that without manure of any kind root crops, after a few years, give scarcely any pro-

duce at all, and hence the results recorded are those obtained by the use of mineral manures, but without any supply of nitrogen.

During the first eight years (four years Norfolk whites and four years Swedes) the turnips gave an average of 42 pounds of nitrogen per acre per annum, or very much more than either of the cereal crops. During the next three years barley yielded 24.3 pounds, or even somewhat less than the yield in wheat or barley with mineral manures in the earlier years of their continuous growth. During the next fifteen years (thirteen with Swedish turnips and two without any crop) the yield was reduced to 18.5 pounds; during the next five years, with sugar-beet, to 13.1 pounds; and during the last five years, to 1880 inclusive, to 15.4 pounds. Lastly, over the whole thirty-six years the average annual yield of nitrogen was 25.2 pounds.

Here, then, compared with wheat or barley, we have with the root crops, the growth of which extends much further into the autumn months, a much higher annual yield of nitrogen in the earlier years, and with this a much more rapid rate of decline subsequently, the annual yield over the last ten years being only about one-third as much as over the first eight years, whilst the yield in the later years is actually less than in either wheat or barley with the same complex mineral manure. Here, again, the marked decline in the yield of nitrogen, with liberal mineral manuring, points to a deficiency in the available supply of nitrogen itself as the cause of the deficient assimilation of it by the crop.

It may here be observed that those who maintain that the atmosphere is an important source of the nitrogen of our crops assume that the root crops, if provided with a small quantity of nitrogenous manure to favor the early development of the plant, will obtain the remainder from the atmosphere. How far this is the case may be illustrated by the following results, which are the average of five years' successive growth of mangel-wurzel on the same plots, and in each case with the same manure year after year.

TABLE II.—*Average produce of mangel-wurzel five years*, 1876—1880

	Roots.		Leaves.	
	Tons.	*Cwts.*	*Tons.*	*Cwts.*
1. Superphosphate of lime, and sulphate potassium	4	10	1	0
2. As 1, and 36½ pounds ammonia salts (=7.8 pounds N.)	6	0	1	6
3. As 1, and 400 pounds ammonia salts (=86 pounds N.)	14	0	2	16

Thus, the annual application of about 7.8 pounds of nitrogen, as ammonia salts, has increased the crop of roots by only 30 cwts. per acre per annum, and the increased yield of nitrogen in the crop was even somewhat less than the amount supplied in the manure. An application of 86 pounds of nitrogen has, however, increased the crop by 160 cwts. more. It is obvious from these facts that the small application of

nitrogen did not enable the plant to take up any from atmospheric sources, and that it required further direct supply of nitrogen to obtain further increase of crop. These results obviously afford confirmation of the view that it was a reduction of the available supply of nitrogen within the soil that was the cause in the decline in the annual yield of the crop and of the amount of nitrogen contained in it.

YIELD OF NITROGEN IN LEGUMINOUS CROPS.

We next come to the consideration of the yield of nitrogen in crops of the leguminous family when these are grown separately year after year on the same land. Plants of this family are said to rely almost exclusively on atmospheric sources for their nitrogen.

Table I shows that without manure beans gave an annual yield over the first twelve years of 48.1 pounds of nitrogen, but over the second twelve of only 14.6 pounds. Over the first period, therefore, the yield was about twice as much as in either wheat or barley, and more even than with the roots. But with this greater yield in the earlier years the reduction is proportionally much greater over the second period, the yield then coming down to less than one-third, and to much the same as in the later periods with the other crops. Over the whole period of twenty-four years, however, there was an annual yield of 31.3 pounds of nitrogen, or more than one and a half times as much as with either wheat or barley, and more than in the roots.

It was seen that in the case of the cereal crops the mixed manure increased the yield of nitrogen but little. Not so in the case of the leguminous crop, beans. During the first twelve years the complex mineral manure (containing a large amount of potash) yielded 61.5 pounds of nitrogen per acre per annum against 48.1 pounds without manure. During the next twelve years the mineral manure gave 29.5 pounds against only 14.6 pounds without manure. During the whole period of twenty-four years the potash manure yielded 45.5 pounds of nitrogen per acre per annum against 31.3 pounds without manure. Lastly, with the mixed mineral manure beans have yielded over a period of twenty-four years more than twice as much nitrogen per acre as either wheat or barley.

But notwithstanding that the beans have for a long series of years yielded so very much more nitrogen over a given area than either of the gramineous crops, and much more also than the root crops, the significant fact cannot fail to be observed that this crop of the leguminous family, which is supposed to rely almost exclusively on the atmosphere for its nitrogen, has declined in yield as strikingly as the other crops, even when grown by a complete mineral manure. Why should this be so if the supply of nitrogen is from the atmosphere and not from the soil?

The results next recorded relate to red clover, and the period of experiment was twenty-two years. It is well known that on most soils a

good crop of clover cannot be relied upon oftener than once in about eight years, and on many soils not so frequently. It will not excite surprise, therefore, that in the course of the twenty-two years of experiment, in only six was any crop of clover obtained, and in some of those only poor ones. Indeed, the plant failed nine times out of ten during the winter and spring succeeding the sowing of the seed. In one year a crop of wheat, and in three years barley, was taken instead; whilst in the remaining twelve years the land was left fallow after the failure of the clover. Still the annual yield of nitrogen over the twenty-two years was 30.5 pounds without any manure, and 39.8 pounds by a complex mineral manure containing potash. Unfavorable as is this result in an agricultural point of view, it is still seen that the interpolation of this leguminous crop has greatly increased the yield of nitrogen compared with that in either wheat or barley grown continuously; and here again, as with beans, a potash manure has considerably increased the yield.

The next experiment affords a still more striking illustration of the large amount of nitrogen that may be taken up in a clover crop; and it further illustrates the fact, well known in agriculture, that the removal of this highly nitrogenous leguminous crop is one of the best possible preparations for the growth of a cereal crop, which characteristically requires nitrogenous manuring. A field which had grown six corn crops in succession by artificial manures alone was then divided, and (in 1873) on one half barley and on the other half clover was grown. The barley yielded 37.3 pounds of nitrogen per acre, but the three cuttings of clover yielded 151.3 pounds. In the next year (1874) barley was grown on both portions of the field. Where barley had previously been grown, and had yielded 37.3 pounds of nitrogen per acre, it now yielded 39.1 pounds; but where the clover had previously been grown, and had yielded 151.3 pounds of nitrogen, the barley succeeding it gave 69.4 pounds, or 30.3 pounds more after the removal of 151.3 pounds in clover than after the removal of only 37.3 pounds in barley. It will be seen further on that this curious result was not in any way accidental.

YIELD OF NITROGEN BY A ROTATION OF CROPS.

The last results recorded in the table relate to the yield of nitrogen in an ordinary four-course rotation of turnips, barley, clover or beans, and wheat. The average yield per annum is given for seven courses, or for a period of twenty-eight years, in one case without any manure during the whole of that time, and in the other with superphosphate of lime alone, applied once every four years, that is, for the turnips commencing each course.

Here with a turnip crop, and a leguminous crop, interpolated with two cereal crops, we have without manure of any kind an average of 36.8 pounds of nitrogen per acre per annum, or very much more than was obtained in either of the cereal crops grown consecutively. With

superphosphate of lime alone, which much increased the yield of nitrogen in the turnips, reduced it in the succeeding barley, increased it greatly in the leguminous crops, and slightly in the wheat succeeding them, the average annual yield of nitrogen is increased to 45.2 pounds, or to about double that obtained in either wheat or barley grown consecutively by a complete mineral manure. On this point it may be further remarked that in adjoining experiments, in which, instead of a leguminous crop, the land was fallowed in the third year of each course, the total yield of nitrogen in the rotation was very much less. In other words, the removal of the most highly nitrogenous crops of the rotation—beans or clover—was succeeded by a growth of wheat, and an assimilation of nitrogen by it, almost as great as when it succeeded a year of fallow; that is, a period of accumulation, and of no removal by crops.

YIELD OF NITROGEN IN THE HERBAGE OF GRASS-LAND.

Another illustration of the amounts of nitrogen removed from a given area of land by different descriptions of crop will be found in Table III, which shows the results obtained when plants of the gramineous, the leguminous, and other families are grown together in the mixed herbage of grass-land.

TABLE III.—*Yield of nitrogen in the mixed herbage of permanent grass-land at Rothamsted.*

Plots.	Conditions of manuring.	Average produce per acre per annum, twenty years, 1856–1875, according to mean per cent., at six periods, 1862, '67, '71, '72, '74, '75.			Average nitrogen per acre per annum.		
		Gramineæ.	Leguminosæ.	Other orders.	Ten years, 1856–1865.	Ten years, 1866–1875.	Twenty years, 1856–1875.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
3	Unmanured	1,635	219	529	35.1	30.9	33.0
4-1	Superphosphate*	1,671	149	673	35.7	31.5	33.6
6	Complex min. man.†	2,443	296	639	54.4	38.1	46.3
7	Complex min. man.‡	2,579	806	573	55.2	56.0	55.6

* Mean of four separations only, namely, 1862, 1867, 1872, and 1875.
† Including potass., six years, 1856–1861; without potass., fourteen years, 1862–1875.
‡ Including potass., twenty years, 1856–1875.

Before referring to the figures attention should be called to the fact that gramineous crops, grown separately on arable land, such as wheat, barley, or oats, contain a comparatively low percentage of nitrogen, and assimilate a comparatively small amount of it over a given area. Yet nitrogenous manures have generally a very striking effect in increasing the growth of such crops. The highly nitrogenous leguminous crops, on the other hand, such as beans and clover, yield, as has been seen, very much more nitrogen over a given area; yet they are by no means characteristically benefited by nitrogenous manuring, whilst their growth is considerably increased, and the yield considerably more nitrogen over

a given area, under the influence of purely mineral manures, and especially of potass. manures. Bearing these facts in mind, the results given in the table will be seen to be quite consistent.

The first three columns in the table show approximately how the mixed herbage was made up under the four different conditions of manuring. It will be observed that without manure, and with superphosphate of lime alone, the amount of the different descriptions of herbage are much the same. Plot 8, with a complex mineral manure including potass. the first six years, but excluding it the next fourteen years, gave a considerable increase of both gramineous and leguminous herbage; whilst plot 7, with a complex mineral manure, including potass. every year of the twenty, there is a still further increase of gramineous herbage, but a very much greater proportional increase of leguminous herbage. It will be observed how much greater is the increase of gramineous produce by the application of purely mineral manures to this mixed herbage than in the case of gramineous crops grown separately. It is a question how far this is due to the mineral manures enabling the grasses to form much more stem and seed, that is, the better to manure, which in fact they do, or how far to an increased amount of combined nitrogen in a condition available for the grasses in the upper layers of the soil, as the result of the increased growth of the Leguminosæ in the first instance, induced by the potass. manure, as in the case of the alternation of clover and barley, and as in the actual course of rotation.

To turn to the yield of nitrogen on the different plots of the mixed herbage, it will be seen that the amounts are almost identical without manure, and with superphosphate of lime alone, about 33 pounds per acre per annum. On plot 8, where a complex mineral manure, including potass. six years, but excluding potass. fourteen years, was employed, the amount is raised to 46.3 pounds, and on plot 7, which received the mixed mineral manure, including potass. every year of the twenty, the yield is 55.6 pounds per acre per annum. Further, without manure, and with superphosphate of lime alone, there was a decline in the yield in the later, compared with the earlier years; with the mineral manure, including potass. only in the first six years, there was a much more marked decline; whilst with the mineral manure, including potass. every year, there was even a slight tendency to an increased yield of nitrogen in the later years.

YIELD OF NITROGEN IN MELILOTUS LEUCANTHA.

One more striking illustration of high nitrogen yield by a plant of the Leguminous family on soil which had not received any nitrogenous manure for nearly thirty years must be given. In 1878, the land upon which attempts had been made to grow red clover in frequent succession since 1849, was devoted to experiments with fourteen different descriptions of leguminous plants; so that the present season, 1882, is

the fifth year of the experiments. The object was to ascertain whether, among a selection of plants all of the Leguminous family, but of different habits of growth, and especially of different character and range of roots, some could be grown successfully for a longer time, and would yield more produce, containing more nitrogen as well as other constituents, than others; all being supplied with the same descriptions and quantities of manuring substances, applied to the surface soil. Further, whether the success in some cases and the failure in others, would afford additional evidence as to the source of the nitrogen of the Leguminosæ generally, and as to the causes of the failure of red clover in particular, when it is grown too frequently on the same land. Fourteen different descriptions of plants were selected, and after two or three immaterial changes the list now includes eight species or varieties of *Trifolium*, two of *Medicago*, *Melilotus leucantha*, *Lotus corniculatus*, *Vicia sativa*, and *Onobrychis sativa:*

Of the numerous species or varieties of *Trifolium* all gave but meager produce, excepting *T. incarnatum*. The *Lotus corniculatus* also gave very small produce. The two species of *Medicago*, the black *Medick*, and the purple *Medick* or Lucerne, and the *Onobrychis*, or common Sainfoin, gave much more; the *Vicia sativa* or common vetch, more still. But of all, the *Melilotus leucantha* or Bokhara clover has yielded the most; and it is estimated that, taking the average of four years, 1878–'81, it has yielded more than 100 pounds of nitrogen per acre per annum, on the plots which have received no nitrogenous manure for more than thirty years; whilst the produce of the fifth season, 1882, is heavier than either of the preceding years. How long this very luxuriant growth and this very high yield of nitrogen per acre will continue, is a question of very great interest. On this point it may be observed that in parts of the continent of Europe, where some of the very free-growing and deep-rooted Leguminosæ are cultivated, it is usual to let them grow for several years, after which they cannot be repeated for twenty years or more. We shall recur to the results above quoted further on.

SUMMARY OF YIELD OF NITROGEN IN CROPS.

The foregoing facts of production, showing the yield of nitrogen in different crops grown without nitrogenous manure, generally for very many years in succession on the same land, may be briefly summed up as follows:

The average yield of nitrogen per acre per annum, was, with wheat, thirty-two years without manure, 20.7 pounds, and twenty-four years with a complex mineral manure, 22.1 pounds; with barley, twenty-four years without manure, 18.3 pounds, and twenty-four years with a complex mineral manure, 22.4 pounds; with root-crops, thirty-six years (including three of barley), with a complex mineral manure, 25.2 pounds; with beans, twenty-four years without manure, 31.3 pounds, and twenty-

four years with a complex mineral manure, 45.5; with clover, six crops in twenty-two years, with one crop of wheat, three crops barley, and twelve years fallow, without manure, 30.5 pounds; with complex mineral manure, 39.8 pounds; with clover on land which had not grown the crop for very many years, one year, 151.3 pounds; with a rotation of crops, seven courses, twenty-eight years without manure, 36.8 pounds; with superphosphate of lime, 45.2 pounds; with the mixed herbage of grass land, twenty years without manure, 33 pounds, and with complex mineral manure, including potass, 55.6; lastly, with Bokhara clover, four years, with mineral manure, more than 100 pounds of nitrogen per acre per annum.

The root-crops yielded more nitrogen than the cereal crops, and the leguminous crops very much more still.

In all the cases of the experiments on ordinary arable land—whether with cereal crops, root crops, leguminous crops, or a rotation of crops (excepting as yet the Bokhara clover)—*the decline in the annual yield of nitrogen, none being supplied* by manure, was very great.

SOURCES OF THE NITROGEN OF CROPS.

We must next consider whence comes the nitrogen of the crops, and especially whence comes the much larger amount taken up by plants of the leguminous, and some other families, than by the graminæ. Lastly, what is the significance of the great decline in the yield of nitrogen in all the crops grown on arable land when none is supplied in the manure?

COMBINED NITROGEN IN RAIN, ETC.

It has been assumed by some that the amount of combined nitrogen annually coming down in the measured aqueous deposits from the atmosphere is sufficient for all the requirements of annual growth. In Liebig's earlier writings he assumed the probability of a very much larger quantity of ammonia coming down in rain than he did subsequently; but even in his more recent work, "The Natural Laws of Husbandry," published in 1863, he supposes that as much as 24 pounds of nitrogen per acre may be annually available to vegetation from that source. Such an amount would, it is obvious, do much towards meeting the requirements of most of the crops the nitrogen statistics of which have been given.

The earliest considerable series of determinations of the amount of ammonia coming down in rain in the open country were by Boussingault, in Alsace. He gives the amount of ammonia per million of rain-water in each fall for a period of between five and six months, May–October, 1852; but he does not calculate the amount so coming down over a given area of land. His average amount per million was, however, somewhat less than that found at Rothamsted in 1853 and 1854, and

found by Mr. Way in Rothamsted rain-water collected in 1855 and 1856; which, calculated according to the rain-fall of the periods, give the following amounts of nitrogen so coming down per acre. The amounts of nitrogen as nitric acid, as determined by Mr. Way, and the amount of total combined nitrogen as ammonia and nitric acid together, are also given.

TABLE IV.—*Nitrogen, as ammonia, and nitric acid, in the rain-fall of three years, at Rothamsted, in pounds per acre.*

Years.	Rainfall.	Nitrogen per acre, as—		
		Ammonia.	Nitric acid.	Total nitrogen.
	Inches.	*Pounds.*	*Pounds.*	*Pounds.*
1853–'5	29.014	5.20	(0.74)	5.94
1855	29.166	5.82	0.72	6.58
1856	27.215	7.28	0.76	8.00
Mean	28.465	6.10	0.74	6.84

It will be seen that according to these results an average of 6.84 pounds was contributed per acre per annum in the rain in the form of ammonia and nitric acid. More recently, however, Dr. Frankland has determined the amount of ammonia and nitric acid in numerous samples of rain and snow water, dew, hoar frost, &c., collected at Rothamsted from April, 1869, to May, 1870, inclusive; and the average amount of ammonia per million of water found by him is considerably lower than the earlier determinations show. More recently still the ammonia has been determined in the Rothamsted laboratory, in the rain of each day separately (if any), for a period of six months, July–December, 1881; also in the proportionally mixed rain for each month, for a period of thirteen months, June, 1881, to June, 1882. The average proportion of ammonia in these most recent determinations accords with the results of Frankland, and point to a smaller amount of total combined nitrogen supplied per acre in the average annual rain-fall at Rothamsted than that recorded in the table; probably, indeed, to not more than four or five pounds of total combined nitrogen per acre per annum.

Dr. R. Angus Smith, in his work entitled "Air and Rain the Beginnings of a Chemical Climatology," 1872, gives the results of numerous analyses of rain-water collected both in country and town districts in the United Kingdom. The amounts of ammonia and nitric acid in the rain vary exceedingly, according to locality; but the amounts in the rain of country places accords generally with those found in the Rothamsted rain-fall.

The following table summarizes the results of numerous determinations made at various stations on the continent of Europe, in each case extending over a whole year:

TABLE 5.—*Nitrogen as ammonia and nitric acid in the rain of various localities Europe.*

[Quantities in pounds per acre per annum.]

Localities.	Years.	Rain-fall.	Nitrogen as—		
			Ammonia.	Nitric acid.	Tot
		Inches.	*Pounds.*	*Pounds.*	*Pou*
Kuschen	1864–'65	11.85	1.44	0.42	1
Do	1865–'66	17.70	1.83	0.67	2
Insterburg	1864–'65	27.55	3.55	1.94	5
Do	1865–'66	23.79	4.14	2.67	6
Dahme	1865	17.09	5.50	1.16	6
Regenwalde	1864–'65	23.48	10.82	4.27	15
Do	1865–'66	19.31	8.27	2.11	10
Do	1866–'67	25.37	13.20	3.24	16
Ida-Marienhütte; mean six years	1865–'70	22.65	.....	.....	9
Proskaw	1864–'65	17.81	13.58	7.33	20
Florence	1870	36.55	9.71	3.65	13
Do	1871	42.48	7.78	2.11	9
Do	1872	50.82	9.50	3.01	12
Vallombrosa	1872	79.83	7.65	2.73	10
Montsouris, Paris	1877–'78	23.62	10.25	1.29	11
Do	1878–'79	25.79	7.05	4.11	11
Do	1879–'80	15.70	4.83	5.69	10
Mean, twenty-two years		27.03	.....	.....	10

It is seen that the numerous very widely varying determinations, some made in the vicinity of towns and some in the open country, give a mean of 10.23 pounds of combined nitrogen annually supplied per acre by rain with a mean rainfall of 27.03 inches. Making all allowance for far inland open country positions on the one hand and for proximity to towns on the other, the very small amounts of combined nitrogen so supplied per acre in some of the cases and the comparatively large quantities in others seem difficult to explain or to reconcile, either with one another or with the results of Boussingault and of Rothamsted. When, however, the comparatively limited and uniform amounts recorded for Montsouris, within the walls of Paris, are considered, 11.54 pounds, 11.16 pounds, and 10.52 pounds per acre per annum, it will not excite surprise that we should estimate the amount of combined nitrogen coming down in the measured aqueous deposits from the atmosphere at probably not more than 5 pounds per acre per annum in the open country at Rothamsted.

With records of the amounts of combined nitrogen contributed to a given area in rain, we come to an end of all quantitative evidence as to the amount of combined nitrogen available to the vegetation of a given area from atmospheric sources. It will be seen how entirely inadequate is the amount probably so available to supply the quantities yielded in different crops without nitrogenous manure, as recorded in the table.

It is true that the minor aqueous deposits from the atmosphere are much richer in combined nitrogen than rain, and there can be no doubt that there would be more deposited within the pores of a given area of soil than on an equal area of the porous even surface of a rain gauge.

How much, however, of this might be available beyond that determined in the collected aqueous deposits, existing evidence does not afford the means of estimating with certainty.

OTHER SUPPOSED SOURCES OF COMBINED NITROGEN.

Further, it has been argued that, in the last stages of the decomposition of organic matter in the soil, hydrogen is evolved, and that this nascent hydrogen combines with the free nitrogen of the atmosphere, and so forms ammonia. Again, it has been suggested that ozone may be evolved in the oxidation of organic matter in the soil, and that, uniting with free nitrogen, nitric acid would be produced.

We have discussed these various possible supplies of combined nitrogen to the soil from atmospheric sources on more than one occasion; and we have given our reasons for concluding that none of them can be taken as accounting for the facts of growth. Incidentally, some evidence will be given further on, confirming the conclusion that any such supplies are limited and inadequate.

But, if the supplies from the atmosphere to the soil itself are inadequate, how about the direct supplies from the atmosphere to the plant?

One view which has been advocated is, that broad-leaved plants have the power of taking up combined nitrogen from the atmosphere, in a manner or in a degree not possessed by the narrow leaved gramineous plants. The only experiments that we are aware of made to determine whether plants can take up nitrogen by their leaves from ammonia supplied to them in the ambient atmosphere are those of Adolph Mayer in Germany, and of Schlössing in France. Both found that very small quantities of nitrogen were so taken up; but both concluded that the action takes place in very immaterial degree in natural vegetation. We have elsewhere shown that not only a consideration of the chemistry and the physics of the subject would lead to the conclusion that the plants which assimilate more nitrogen over a given area than others do not do so by virtue of a greater power of absorbing already combined nitrogen from the atmosphere by their leaves. But, apart from such considerations, our statistics of nitrogen production seem to preclude the idea that the broad-leaved root crops, turnips, and the like, to which the function has with the most confidence been attributed, take up any material proportion of their nitrogen by their leaves from combined nitrogen in the atmosphere. We need only here recall attention to the fact that the yield of nitrogen in these crops, even with the aid of a complex mineral manure, was in the later years reduced to as low a point as in the case of the narrow-leaved cereals.

DO PLANTS ASSIMILATE FREE NITROGEN?

The question still remains whether plants assimilate the free nitrogen of the atmosphere, and whether some descriptions do so in a much greater degree than others. It is freely admitted that if this were established many of our difficulties would vanish.

This question has been the subject of a great deal of experimental inquiry, since the time that Boussingault entered upon it about the year 1837; and more than twenty years ago it was elaborately investigated at Rothamsted.

We will here give a summary of the very conflicting results which have been published in reference to this subject of the assimilation of the free nitrogen of the atmosphere by plants, confining attention for want of space to the three most comprehensive series of experiments which have been undertaken relating to it.

Though not the first in point of date, we will first refer to the experiments of M. G. Ville, the results of which led him to conclude that plants do assimilate the free nitrogen of the air—a view of which he has been the archapostle for many years, and upon which he may be said to have founded a system in his work on "Artificial Manures."

From 1849 to 1856, M. G. Ville made numerous experiments on this subject. The following table (V) gives a summary of his results, and shows the special conditions of each separate series of experiments:

TABLE V.—*Results of M. G. Ville's experiments to determine whether plants assimilate free nitrogen.*

Plots.	Nitrogen, grams.			
	In seed and air, and manure, if any.	In products.	Gain or loss.	Nitrogen in products to 1 supplied.
1849. Current of unwashed air supplying 0.001 grams nitrogen as ammonia: (1)				
Cress	0.0260	0.1470	0.1210	5.6
Large lupins	0.0640	0.0640	0.0000	1.0
Small lupins	0.0640	0.0470	—0.0170	0.7
	0.1550	0.2580	0.1030	1.7
1850. Current of unwashed air supplying 0.0017 grams nitrogen as ammonia: (1)				
Colza (plants)	0.0260	1.0700	1.0440	41.1
Wheat	0.0160	0.0310	0.0150	1.9
Rye	0.0130	0.0370	0.0240	2.8
Maize	0.0290	0.1280	0.0990	4.4
	0.0857	1.2660	1.1803	14.8
1851. Current of washed air: (1)				
Sunflower	0.0050	0.1570	0.1520	31.4
Tobacco	0.0040	0.1750	0.1710	43.7
Tobacco	0.0040	0.1620	0.1580	40.5
1852. Current of washed air: (1)				
Autumn colza	0.0480	0.2260	0.1780	4.7
Spring wheat	0.0290	0.0650	0.0360	2.2
Sunflower	0.0160	0.4080	0.3920	25.5
Summer colza	0.1730	0.5950	0.4220	3.4
Summer colza	0.1050	0.7010	0.5960	6.7
1854. Current of washed air (under superintendence of a commission):				
Cress	0.0099	0.0097	—0.0002	1.0
Cress	0.0038	0.0530	0.0492	13.9
Cress	0.0039	0.0110	0.0071	2.
1854. Current of washed air (closed under superintendence of a commission): (2)				

(1) Recherches Experimentates sur la Végétation, par M. Georges Ville, Paris, 1853.
(2) Compt. rend.: 1855.

TABLE V—Continued.

Plots.	Nitrogen, grams.			Nitrogen in products to 1 supplied.
	In seed and air, and manure, if any.	In products.	Gain or loss.	
Cress	0.0063	0.0350	0.0 87	5.6
1855 and 1856. In pure air, with 0.5 gram nitre = 0.069 nitrogen: (1)				
Colza	0.0700	(2)0.0700	0.0000	1.0
Colza	0.0700	(2)0.0660	—0.0040	0.9
Colza	0.0700	(2)0.0680	—0.0020	1.0
1855 and 1856. In free air, with 1 gram nitre = 0.138 nitrogen: (1)				
Colza	0.1400	(2)0.1970	0.0570	1.41
Colza	0.1400	(2)0.3740	0.2340	2.67
Colza	0.1400	(2)0.2160	0.0760	1.54
Colza	0.1400	(2)0.2500	0.1100	1.79
1856. In free air, with 0.792 gram nitre = 0.110 nitrogen: (1)				
Wheat	0.1260	(2)0.2180	0.0920	1.7
Wheat	0.1260	(2)0.2240	0.0980	1.8
1855. In free air, with 1.72 grams nitre = 0.238 nitrogen: (1)				
Wheat	0.2590	(2)0.3080	0.0490	1.2
1856. In free air, with 1.765 grams nitre = 0.244 nitroge: (1)				
Wheat	0.2650	(2)0.2170	—0.0480	0.8
Wheat	0.2650	(2)0.3500	+0.0850	1.3

(1) Recherches Experimentales sur la Végétation, 1857.
(2) In plants only.

These results, as well as those of others, we have fully discussed elsewhere (Phil. Trans., 1859, and Jour. Chem. Soc., vol. xvi, 1863), and we can only very briefly refer to them in this place.

The column of actual gain or loss, shows in one case, with colza, a gain of more than 1 gram of nitrogen; and the amount in the products is more than forty-one times as much as that supplied as combined nitrogen in the seed and air. The results with wheat, rye, or maize showed very much less of both actual and proportional gain. Experiments with sunflower showed in one case thirty fold, and with tobacco in two cases more than forty fold, as much in the products as was supplied. It will be observed, however, that upon the whole M. G. Ville's later experiments showed considerably less both actual and proportional gain than his earlier ones.

M. G. Ville in some cases attributed the gain to the large leaf surface. In explanation of the assimilation of free nitrogen by plants, he calls attention to the fact that nascent hydrogen is said to give ammonia, and nascent oxygen nitric acid, with free nitrogen, and he asks: Why should not the nitrogen in the juices of the plant combine with the nascent carbon and oxygen in the leaves? He refers to the supposition of M. De Luca, that the nitrogen of the air combines with the nascent oxygen given off by the leaves of plants, and to the fact that the juice of some plants (mushrooms) has been observed to ozonize the oxygen of the air, and he asks: Is it not probable, then, that the nitrogen dissolved in the juices will submit to the action of the ozonized oxygen with which it is mixed, when we bear in mind that the juices contain alkalies, and penetrate tissues, the porosity of which exceeds that of spongy platinum?

The following table (VI) summarizes the results of M. Boussingault. His experiments on the subject commenced in 1837, and were continued at intervals up to 1858. The conditions of each set of experiments as to soil, air. or application of manurial substances, are given in the table.

TABLE VI.—*Results of M. Boussingault's experiments to determine whether plants assimilate free nitrogen.*

Plants.	Nitrogen, grams.			
	In seed or plants, and manure, if any.	In manure.	Gain or loss.	Nitrogen in products to 1 supplied.
1837. Burnt soil, distilled water, free air in closed summer house: (1)				
Trefoil	0.1100	0.1200	+0.0160	1.00
Trefoil	0.1140	0.1560	+0.0420	1.37
Wheat	0.0430	0.0400	—0.0030	0.93
Wheat	0.0570	0.0600	+0.0030	1.05
1838. Conditions as in 1837: (2)				
Peas	0.0460	0.1010	+0.0550	2.20
Trefoil (plants)	0.0330	0.0560	+0.0230	1.70
Oats (plants)	0.0590	0.0530	—0.0060	0.90
1851 and 1852. Washed and ignited pumice with ashes, distilled water, limited air, under glass shade, with carbonic acid: (3)				
Haricot, 1851	0.0349	0.0340	—0.0009	0.97
Oats, 1851	0.0078	0.0067	—0.0011	0.86
Haricot, 1852	0.0210	0.0189	—0.0021	0.90
Haricot, 1852	0.0245	0.0226	—0.0019	0.92
Oats, 1852	0.0031	0.0030	—0.0001	0.97
1853. Prepared pumice, or burnt brick, with ashes; distilled water, limited air, in glass globe, with carbonic acid: (3)				
White lupin	0.0480	0.0483	+0.0003	1.01
White lupin	0.1282	0.1246	—0.0036	0.97
White lupin	0.0349	0.0339	—0.0010	0.97
White lupin	0.0200	0.0204	+0.0004	1.02
White lupin	0.0399	0.0397	—0.0002	1.00
Dwarf haricot	0.0354	0.0360	+0.0006	1.02
Dwarf haricot	0.0298	0.0277	—0.0021	0.93
Garden cress	0.0013	0.0013	0.0000	1.00
White lupin	0.1827	0.1697	—0.0130	0.93
1854. Prepared pumice with ashes, distilled water, current of washed air, and carbonic acid, in glazed case: (4)				
Lupin	0.0196	0.0187	—0.0009	0.95
Dwarf haricot	0.0322	0.0325	+0.0003	1.01
Dwarf haricot	0.0335	0.0341	+0.0006	1.02
Dwarf haricot	0.0339	0.0329	—0.0010	0.97
Dwarf haricot	0.0676	0.0666	—0.0010	0.99
Lupin	0.0180	0.0334	—0.0021	0.94
Lupin	0.0175			
Cress	0.0046	0.0052	—0.0006	1.13
1851, '52, '53, and '54. Prepared soil, or pumice with ashes; distilled water, free air, under glazed case: (4)				
Haricot (dwarf), 1851	0.0349	0.0380	+0.0031	1.09
Haricot, 1853	0.0213	0.0238	+0.0025	1.12
Haricot, 1853	0.0293	0.0270	—0.0023	0.92
Haricot (dwarf), 1854	0.0318	0.0350	+0.0032	1.10
Lupin (white), 1853	0.0214	0.0256	+0.0042	1.20
Lupin, 1854	0.0199	0.0229	+0.0030	1.15
Lupin, 1854	0.0367	0.0387	+0.0020	1.05
Oats, 1852	0.0031	0.0041	+0.0010	1.32
Wheat, 1853	0.0064	0.0075	+0.0011	1.17
Garden cress, 1854	0.0259	0.0272	+0.0013	1.05
1858. Nitrate of potassium as manure: (5)				
Helianthus	(6) 0.0144	0.0130	—0.0014	0.90
	(6) 0.0255	0.0245	—0.0010	0.96

(1) Ann. Ch. Phys. [2], lxvii (1838).
(2) Ibid, lxix.
(3) Ann. Ch. Phys. [3], xli (1854).
(4) Ann. Ch. Phys. Ser. [3], xliii (1855).
(5) Compt. rend.. xlvii (1858).
(6) Nitrogen in seed and nitrate.

The last two columns of the table ( ) show the actual and proportional gain or loss of nitrogen in M. Boussingault's experiments. It will be seen that in his earlier experiments, those in free air in a summer house, the leguminous plants, trefoil and peas, did indicate a notable gain of nitrogen; but in all his subsequent experiments there was generally either a slight loss, or, if a gain, it was represented in only, fractions or low units of milligrams. After twenty years of varied and laborious investigation of the subject, M. Boussingault concluded that plants have not the power of assimilating the free nitrogen of the atmosphere. And in a letter received from him as recently as 1876, after discussing several aspects of the question, he says:

> If there is one fact perfectly demonstrated in physiology, it is this of the non-assimilation of free nitrogen by plants; and I may add by plants of an inferior order, such as micoderms and mushrooms.—(Translation.)

Our own experiments on this subject were commenced in 1857, and a young American chemist, the late Dr. Pugh, of the Pennsylvania State Agricultural College, devoted between two and three years to the investigation at Rothamsted. The conditions of the experiments and the results obtained up to that date are fully described in the papers in the Philosophical Transactions for 1859 and in the Journal of the Chemical Society, in 1863, already referred to. Table VII summarizes the results obtained.

TABLE VII.—*Results of experiments made at Rothamsted to determine whether plants assimilate free nitrogen.*

With *no* combined nitrogen supplied beyond that in the seed sown.

	Nitrogen, grams.			
	In seed and manure, if any.	In plants, pot, and soil.	Gain or loss.	Nitrogen in products to 1, supplied.
GRAMINEÆ.				
1857:				
Wheat	0.0080	0.0072	—0.0008	0.90
Barley	0.0056	0.0072	+0.0016	1.11
Do	0.0056	0.0082	+0.0026	1.46
1858:				
Wheat	0.0078	0.0081	+0.0003	1.04
Barley	0.0057	0.0058	+0.0001	1.02
Oats	0.0063	0.0056	—0.0007	0.89
1858, A 1:				
Wheat	0.0078	0.0078	0.0000	1.00
Oats	0.0064	0.0063	—0.0001	0.98
LEGUMINOSÆ.				
1857:				
Beans	0.0796	0.0791	—0.0005	0.99
1858:				
Beans	0.0750	0.0757	+0.0007	1.01
Pease	0.0188	0.0167	—0.0021	0.89
OTHER PLANTS.				
1858:				
Buckwheat	0.0200	0.0182	—0.0018	0.91

TABLE VII—Continued.

With combined nitrogen supplied beyond that in the seed sown.

	Nitrogen, grams.			
	In seed and manure, if any.	In plants, pot, and soil.	Gain or loss.	Nitrogen in products to 1, supplied.
GRAMINEÆ.				
1857:				
Wheat	0.0329	0.0383	+0.0054	1.16
Do	0.0329	0.0331	+0.0002	1.01
Barley	0.0326	0.0328	+0.0002	1.01
Do	0.0268	0.0337	+0.0069	1.25
1858:				
Wheat	0.0548	0.0536	−0.0012	0.98
Barley	0.0496	0.0464	−0.0032	0.94
Oats	0.0312	0.0216	−0.0096	0.69
1858, A 1:				
Wheat	0.0268	0.0274	+0.0006	1.02
Barley	0.0257	0.0242	−0.0015	0.94
Oats	0.0260	0.0198	−0.0062	0.76
LEGUMINOSÆ.				
1858:				
Pease	0.0227	0.0211	−0.0016	0.93
Clover	0.0712	0.0665	−0.0047	0.93
1858, A 1:				
Beans	0.0711	0.0655	−0.0056	0.92
OTHER PLANTS.				
1858:				
Buckwheat	0.0308	0.0292	−0.0016	0.95

A 1. These experiments were conducted in the apparatus of M. G. Ville.

The upper part of the table shows the results obtained in the experiment in which no combined nitrogen was supplied beyond that contained in the seed sown. The growth was in all cases extremely restricted, and the figures show that there was in no case, whether of gramineæ, leguminosæ, or buckwheat, a gain indicated by as much as three milligrams of nitrogen. There was in most cases much less gain or a slight loss.

The lower part of the table shows the results obtained when the plants were supplied with known quantities of combined nitrogen in the form of a solution of ammonium sulphate applied to the soil. The actual gains or losses range a little higher in these experiments, with larger quantities of nitrogen involved; but they are always represented by units of milligrams only, and the losses are higher than the gains. Further, the gains, such as they are, are all in the experiments with the gramineæ, whilst there is in each case a loss with the leguminosæ and the buckwheat.

It should be stated that the growth was far more healthy with the gramineæ than with the leguminosæ, which are even in the open field very susceptible to vicissitudes of heat and moisture, and were especially so when inclosed under glass shades. It might be objected, therefore, that the negative results with the leguminosæ are not so conclu-

sive as those with the gramineæ. Nevertheless, we do not hesitate to conclude from our own experiments, as Boussingault did from his, that the evidence is strongly against the supposition that either the gramineæ or the leguminosæ assimilate the free nitrogen of the atmosphere.

RECAPITULATION.

In the foregoing resumé of mostly previously recorded fact, we have shown the amount of nitrogen assimilated by various crops over a given area when grown for many years in succession on the same land without any nitrogenous manure; that is, under conditions in which the source of the nitrogen is as little as possible obscured by the influence of indefinite amounts available from manure. It has been shown that the determined amounts of combined nitrogen annually coming down in the measured aqueous deposits from the atmosphere in the open country are entirely insufficient to do more than supply a small proportion of the nitrogen assimilated by crops so grown. With regard to other possible supplies of already combined nitrogen from the atmosphere to the soil, it has been pointed out that there is no quantitative evidence whatever at command, and that such evidence as does exist leads to the conclusion that such supplies are very limited and inadequate. The same may be said, even in a greater degree, of the supposed combination of the free nitrogen of the air within the soil; also of the supposition that plants take up any material proportion of their nitrogen from combined nitrogen in the atmosphere by their leaves. Finally it has been concluded that the balance of direct experimental evidence is decidedly against the supposition that plants assimilate the free nitrogen of the atmosphere. Indeed, the strongest argument that we know of in favor of such a supposition is that, in defect of other conclusive evidence, some such explanation of the facts of production would seem to be needed.

THE NITROGEN OF THE SOIL A SOURCE OF THE NITROGEN OF CROPS.

We now turn to that part of the subject which it is the special object of this communication to bring forward, namely, the determinations of nitrogen in the soils of some of the experimental fields at Rothamsted, the yield in nitrogen of which has been given, and to show the bearing of the results on the question of the sources of the nitrogen of the crops.

We have no wish or intention to ignore the difficulties inherent in the treatment of the subject from this point of view. The difficulty of the problem will at once be recognized when it is borne in mind that a difference of .001 in the percentage of nitrogen in the dry soil may represent a difference of from 20 to 25 pounds of nitrogen per acre, in a layer of 9 inches in depth. Again, when it is further borne in mind that, in the case of the Rothamsted arable soils with which we have to deal, the percentage of nitrogen in the first 9 inches of depth is sometimes

only about 0.1, and seldom exceeds .14 or .15; that the percentage in the second 9 inches ranges from under .06 to about .07, and that that of the lower depths is rather lower still, it will be seen that if any quantitative estimates are to be based on the percentage amounts of nitrogen determined in samples of soil from different depths, the greatest care must be taken to insure that the samples truly represent the exact depth supposed. The mode usually adopted of taking samples of an indefinite area, perhaps not to a definite depth, and almost certainly not of uniform breadth or width to the depth taken, is obviously quite inapplicable for the purposes of any such inquiry as that supposed.

Unfortunately, the few samples of soil that were collected in the early years of the Rothamsted field experiments were not taken in such a manner as to afford results applicable to our purpose. Commencing in 1856, however, the mode adopted has been, after carefully leveling the soil, to drive down a square frame, made of strong sheet iron, open at top and bottom, and of an exact area, and of an exact depth, to the level of the surface. The inclosed soil is then carefully taken out, and its weight determined. The soil around the frame is then removed to the level of its lower edge, and it is again driven down, and the inclosed soil removed; and this process is repeated until the desired depth of sampling is reached.

Of surface soils, samples are taken from three, four, or as many as eight places on the same plot. A portion of each such sample is kept separate, as a means of testing the range of variation, and, if need be, of correction in case of any abnormal results due to accidental animal droppings or other causes. Another portion of each separate sample is used to make a mixture of all. In the case of the subsoils, the separate samples of corresponding depth from the same plot are at once mixed. Surface soils are sometimes taken of an area of 12 by 12 inches, but sometimes of only 6 by 6 inches, and subsoils almost invariably of the smaller area. The depth of each sample is generally 9 inches; but in some special cases it has been only 3 inches, and in some 6 inches. It is perhaps to be regretted that the depth originally fixed upon did not more nearly represent that to which the soil is more directly affected by the mechanical operations, and by the application of manure, say 6 inches. But having originally adopted 9 inches, it has been necessary to adhere to this depth subsequently, in order, as far as possible, to obtain comparable results at different dates.

The soils when brought to the laboratory are first broken up and partially dried in a stove room at a temperature of about 130° F. to arrest nitrification, which would be liable to take place if the soils were moist. Next the stones are removed; first those retained by a sieve of 1-inch mesh, next by a sieve of one-half-inch mesh, and then by a one-fourth inch sieve. All that passes the one-fourth inch sieve is termed the *mold*. Portions of this are very finely powdered and sifted for ana-

lysis, and the weights being recorded at each stage of preparation, and the water lost on drying at 100 C being determined on the finely powdered mold, all results of analysis are calculated into percentage on the so-determined *dry mold*. From the same data the amount of *dry mold* per acre is calculated, and upon this the amount of nitrogen per acre. It will be seen further on, that notwithstanding the means adopted to secure uniformity, the amounts of dry mold per acre calculated for a given depth from the samples taken vary considerably for the same field at different times, according to the dryness or wetness of the season, the condition of the land as affected by the crop, the mechanical operations, and other circumstances. The amounts also vary very considerably for the soils of adjoining fields.

NITROGEN IN THE SOILS OF THE EXPERIMENTAL WHEAT PLOTS.

The first series of determinations of nitrogen to which attention will be called relates to those made in the soils of some of the plots of Broadbalk field, which has now grown wheat for thirty-nine years in succession, and the yield of nitrogen in which, on the plots receiving no nitrogen in manure, has been given in Table I. It will be remembered that, under those conditions, there was a very marked decline in the annual yield of nitrogen in the crop, both without any manure and with a mixed mineral manure used alone.

The first wheat crop of the series was harvested in 1844, and although isolated samples of the soil were taken in the early years, it was not until 1856 that any were collected on the plan now followed. At that date only four plots were sampled, and only to the depth of the first 9 inches. Eight samples were, however, taken from each plot, each 12 by 12 inches area, and the eight were mixed together. In 1865, samples were taken from eleven plots, from eight places on each plot, each sample 12 by 12 inches area, and this time to a depth three times 9 inches, or to a total depth of 27 inches. Lastly, in 1881, twenty plots were sampled; six samples, each 6 by 6 inches area, were taken from each plot, and in each case to three depths of 9 inches each, or in all to 27 inches.

Thus, it is only in 1865 and in 1881 that we have any considerable series of samples and the nitrogen determined in them; that is, in 1865 after the twenty-second, and in 1881 after the thirty-eighth crop had been removed. It is obvious that, if the results at these two periods are to be compared, we must first determine whether the samples taken represent layers of equal depth and weight in the two cases. Confining attention on the present occasion to the results relating to the first 9 inches of depth, the following figures show the average weight of dry mold per acre, that is, of soil excluding stones and moisture, calculated from the weight of the samples taken, and from the results of the mechanical separation, and of the determination of moisture in the soils.

For 1865, the calculations are based on the results afforded by eig samples, eight from each of ten of the eleven plots, the eleventh b the one annually receiving farm-yard manure; and for 1881 they based on the results relating to one hundred and fourteen samples, is, six samples each from nineteen plots, again excluding the one farm-yard manure.

Number of samples.	Calcu dry per
	Pou
1865, 10 plots, eight samples from each	2,
1881, 19 plots, six samples from each	2,

The importance of taking samples of definite area and depth, and determining the weights, is here strikingly illustrated. Thus, it is vious that the samples analyzed in 1881 represented, on the avera almost exactly one-ninth more soil per acre than those analyzed in 18 In other words, if the samples of 1865 fairly represented 9 inches depth in the average condition of consolidation of the soil, those of 18 represented 10 inches of soil in the same condition; that is, they cluded 1 inch more of subsoil, with its much lower percentage of nit gen than the 9 inches above it. It may, of course, be a question wheth the condition of consolidation of the soil was the more normal at t one period or at the other; and it would make scarcely any difference the relation of the results to one another at the two periods, wheth the actually determined percentages of nitrogen in the 1865 sampl were lowered on the assumption that they should have included 1 inc more of subsoil, or whether the determined percentages in the 18 samples are raised on the assumption that they contained 1 inch t much of subsoil. We have concluded, from a consideration of all th facts at command, that the latter alternative is upon the whole the bes We adopt, therefore, the percentages of nitrogen as actually determine in the 1865 samples, and we assume the weight of mold (9 inches deep represented by the samples to be 2,300,000 pounds per acre. But in th case of the 1881 samples we assume that one-tenth of the heavier weig had the composition determined in the second 9 inches (it would be ver slightly higher), and the percentage in the remaining nine-tenths, rep resenting 2,300,000 pounds of surface soil, is raised by calculation ac cordingly.

The following table (VIII) gives for the surface soils (9 inches deep), o the unmanured plot, and the nine artificially manured plots sampled in 1865, the actually determined percentages of nitrogen in the dry mold and for the 1881 samples from the same plots, both the actually deter mined percentages and the corrected percentages, calculated as abov described. The table also shows the amount of nitrogen per acre, reck o ning 2,300,000 pounds of dry mold, calculated for 1865 according to th

ially determined percentages, and for 1881 according to the corrected centages. The quantities per acre more (+) or less (—) in 1881 n in 1865 are also given. Lastly, for each period are given the quanes more or less on each of the other plots than on plot 5*a*, which ived the mineral manure alone.

TABLE VIII.—BROADBALK FIELD SOILS.

Nitrogen per cent. in the dry mold and per acre.

[Wheat thirty-nine years in succession, 1843–'4 to 1881–'2, inclusive.]

	Nitrogen.								
	Per cent. in dry mold.			Per acre, 2,300,000 pounds dry mold,					
	1865.	1881.		1865.	1881.	1881 + or — 1865.	+ or — plot 5*a*.		
	Actual.	Actual.	Corrected.				1865.	1881.	1881 + or — 1865.
	Per ct.	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Unmanured	0.1090	0.1009	0.1045	2,507	2,404	—103	.....	.....	.....
Mixed mineral manure	0.1119	0.0981	0.1012	2,574	2,328	—246	.....	.....	.....
Mixed mineral manure and ammonia salts, = 86 pounds nitrogen.	0.1230	0.1207	0.1264	2,829	2,908	+ 79	+255	+580	+325
Mixed mineral manure and nitrate of soda, = 86 pounds nitrogen.	0.1232	0.1200	0.1253	2,834	2,883	+49	+260	+555	+295
Ammonia salts, = 86 pounds nitrogen (1845 and since).	0.1108	0.1034	0.1074	2,548	2,471	—77	—26	+143	+169
Ammonia salts, = 86 pounds nitrogen and superphosphate.	0.1171	0.1121	0.1164	2,693	2,676	—17	+119	+348	+229
Ammonia salts, = 86 pounds nitrogen, superphosphate, and soda.	0.1208	0.1155	0.1202	2,778	2,765	—13	+204	+437	+233
Ammonia salts, = 86 pounds nitrogen, superphosphate, and potassa.	0.1206	0,1191	0.1245	2,774	2,863	+89	+200	+535	+335
Ammonia salts, = 86 pounds nitrogen, superphosphate, and magnesia.	0.1197	0.1163	0.1215	2,753	2,794	+41	+179	+466	+287
Ammonia salts, = 172 pounds nitrogen and mixed mineral manure.	0.1264	0.1066	0.1122	2,907	2,557	—350	+333	+229	—104

As already said, in 1865 the land had grown twenty-two crops, and 1881 thirty-eight crops of wheat in succession. Plot 3 had been nmanured from the commencement. Plot 10*a* received mineral manure in the first year, but the ammonia salts alone each year since. The maining plots were somewhat variously manured during the first ight of the thirty-eight years; but (excepting plot 16) each has been nanured every year for the last three of the thirty-eight years, as disribed in the table.

It will be observed that for every plot, the actual determinations show lower percentage of nitrogen in 1881 than in 1865. The corrected percentages for 1881 are, of course, all rather higher than the actual determinations, and they, in some cases, show a higher and in others a lower percentage than in 1865. Nevertheless, it cannot fail to be noted that

the rotation of plot to plot is essentially accordant at the two period The significance of the results will, however, be rendered the more a parent on an examination of the calculated quantities per acre. It obvious that absolute accuracy cannot be claimed for such figures, b the general accordance of the indications at the two periods is such a to leave no doubt of their import.

Keeping in view the special object of this communication, which is t show the bearing of what may be called the nitrogen statistics of th soils, on the question of the source of the nitrogen in the crops, it wi be seen that during the sixteen years, from 1865 to 1881, both the u manured plot (3) and the mineral manured plot (5*a*), the yield of nitro gen in the crops of which declined so strikingly, show a great reductio in the stock of nitrogen in the surface soil. The reduction in thes later years is considerably greater in the surface soil of the mineral ma nured than in that of the entirely unmanured plot, the previous accu mulation in which had been many more years subject to exhaustion Taking the results, however, for the first, second, and third 9 inches the calculated loss to the depth of 27 inches is approximately the sam for the two plots. The figures recorded for the first 9 inches only are however, sufficient to show that the decline in the yield of nitrogen i the crop where none has been supplied in manure, is accompanied by t decline in the stock of nitrogen in the soil.

A further illustration on this point is afforded by the results for plot 16*a*. For the thirteen years, 1852–1864, plot 16 received, besides the mixed mineral manure, twice as much ammonium-salts as any of the other plots, the results for which are given in the table, and it gave on the average of those years 39½ bushels of grain per acre per annum. Since 1864, however, the plot has been left unmanured, and during the seven teen years, 1865–1881, it has yielded an average of only 14¾ bushels of grain; and in recent years the produce has been very little more than with out manure, or with purely mineral manure. The table shows that in 1865, that is, after one crop had been removed since the application of the excess of ammonia salts, the surface soil still contained considerably more nitrogen than any other plot in the series. In 1881, however, after sixteen years more of cropping without manure, the stock of nitrogen on the plot was reduced by a greater amount than on any other plot, and to a lower point than on any other of the ammonium plots, except ing plot 10 with the ammonium salts alone.

Let us now refer to the last three columns in the table, which shows for each of the plots receiving ammonium salts the amount of nitrogen per acre in the surface soil, more or less than in that of plot 5*a*, with min eral manure alone. All the plots, 7 to 14 inclusive, received the same quantity of nitrogen, namely, 86 pounds per acre per annum. But it will be seen that the excess of nitrogen in the surface soils compared with the mineral manured plot 5, varies exceedingly; in fact, it is ob vious that the amounts have no direct relation to the amount of nitro-

n supplied in the manure. The following table will afford some exanation of these differences. The plots under consideration, all of which ceived the same amount of nitrogen in manure, are there given in the der of their average annual increased yield of nitrogen in the crops er plot 5. The first column shows the estimated average annual inased yield of nitrogen per acre in the crops; the second, the estimated nual loss of nitrogen as nitric acid by drainage; the third, the estiated annual excess of nitrogen in the surface soil over that on plot with the mineral manure alone; and the last column shows the relaon which that excess in the soil bears to 100 increased yield in the ops.

TABLE IX.—*Estimated nitrogen per acre per annum.*

		In crops over plot 5.	Loss by drainage over plot 5.	In soil 9 inches deep over plot 5.	Excess in soil to 100 increase in crop.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
10	Amm. salts = 86 pounds N. (1845 and since)	12.4	31.2	4.8	38.7
11	Amm. salts = 86 pounds N. and superphosphate	17.7	28.5	11.6	65.5
12	Amm. salts = 86 pounds N. superphos. and soda	22.2	24.5	14.6	65.8
13	Amm. salts = 86 pounds N. superphos. and potass	23.4	25.6	17.8	76.1
14	Amm. salts = 86 pounds N. superphos. and mag'a	24.1	27.5	15.5	64.3
7	Amm. salts = 86 pounds N. and mixed min. man	25.9	19.0	19.3	74.5
9	Nit. soda = 86 pounds N. and mixed min. man	26.0	23.7	18.5	71.2

It is seen that the increased yield of nitrogen in the crops also varied exceedingly with the same amount supplied in manure, according to the condition as to supply of mineral constituents. Plot 10, with the ammonium salts alone, gives the smallest increased yield of nitrogen in the crop; and plots 7 and 9, with the most complete mineral manure, each more than twice as much; the other plots giving intermediate amounts. The order of the estimated loss of nitrogen by drainage is almost the converse of that of the increased yield in the crops. Plot 10, which gives the least increased yield in the crop, shows the greater loss by drainage; and plots 7 and 9, which yield the greatest increase in the crop, show the least loss by drainage. The excess in the soils (over plot 5) is obviously much more in the order of the increased yield in the crops. Plot 10, with the least in the increase of crop and the most in the drainage, shows the least excess in the soil, whilst plots 7 and 9, with the greatest increased yield in the crop and the least loss by drainage, show the greatest excess in the soil.

It is clear, therefore, that whilst the excess in the soil has no direct relation to the amount supplied in the manure, it has a very obvious relation to the increased yield in the crop; in other words, to the amount of growth. The last column of the table brings this out more clearly. Excepting in the case of plot 10, with the ammonium salts alone, there is a general uniformity in the proportion of the excess in the soil over plot 5

to the increased yield in the crop over plot 5; and the variations, such as they are, have an obvious connection with the conditions of growth. Thus, plots 11, 12, and 14, all with a deficient supply of potass, show approximately equal proportions retained in the soil for 100 of increase in the crop. Plots 13, 7, and 9, again, all with liberal supplies of potass, show higher, but approximately equal, proportions retained in the surface soil for 100 of increased yield in the crop. Upon the whole, it is obvious that the relative excess of nitrogen in the soils of the different plots is little, if at all, due to the direct retention by the soil of the nitrogen of the manure, but is almost exclusively dependent on the difference in amount of the residue of the crops—of the stubble and roots, and perhaps of weeds.

Recurring to the main point, which it is our object to elucidate, there can be no doubt that the determinations of nitrogen in the surface soils of the different plots of the experimental wheat field, at different dates, establish the fact that the decline in the yield of nitrogen in the crops is accompanied by a decline in the stock of nitrogen in the soil. It will be well to consider as far as the data at command will allow, what relation the yield of the nitrogen in the crops bears to the loss of nitrogen by the soil? On this point it may be stated that, taking the average of thirty years, 1852–1881, it is estimated that the unmanured plot yielded 18.6 pounds of nitrogen in the crops and 10.3 pounds in the drainage, or in all 28.9 pounds per acre per annum over that period. In like manner it is estimated that plot 5, which received nitrogenous as well as mineral manure during the preceding eight years, but mineral manure alone during the thirty years, yielded 20.3 pounds of nitrogen in the crops and 12 pounds in the drainage, or in all 32.3 pounds per acre per annum. It would thus appear that without nitrogenous manure about 30 pounds of nitrogen has been contributed per acre per annum to crop and drainage together. The determinations of nitrogen in the soils of the two plots indicate that they have lost an average of about two-thirds of this amount annually to the depth of 27 inches. There would, therefore, according to this reckoning, remain about one-third—say 10 pounds more or less—to be contributed by seed, by rain, and condensation from the atmosphere, and by all the other supplies of combined nitrogen, which have been supposed to be available, whether of the combination of free nitrogen within the soil, or its assimilation by the plant. Of this amount about 2 pounds will be due to seed, and if we suppose, say, only 5 pounds to be annually supplied by rain and the minor aqueous deposits from the atmosphere, there is but little left to be provided by all the other sources assumed.

NITROGEN IN THE SOILS OF THE EXPERIMENTAL BARLEY PLOTS.

Unfortunately we have not so complete a series of determinations of nitrogen in the soils of the experimental barley plots as of those in the experimental wheat field. In 1868 four of the barley plots were sampled,

four samples, each 6 by 6 inches area, by 9 inches deep, were taken from each plot, and the four mixed together. In March, 1882, 26 plots were sampled, four samples being taken from each plot, each 6 by 6 inches area, and to the depth of three times 9 or 27 inches. Of the plots sampled in 1868 only one had received no nitrogenous manure, but we are able to give the percentage of nitrogen in the surface soil of this plot at the two dates.

TABLE X.—HOOSFIELD BARLEY LAND.

Nitrogen, per cent. in the dry mold, first 9 inches.

[Barley thirty-one years in succession, 1852–1882 inclusive.]

Kind of manure.	1868.	1882.
	Per cent.	*Per cent.*
Mixed mineral manure alone	0.1202	0.1124

The calculated average weights of dry mold per acre, to the depth of 9 inches, were not very different at the two dates. The 1882 samples were, however, slightly the heavier, which would indicate that, for comparison, the percentage of nitrogen given for the later date is perhaps somewhat too low. Still, it is obvious that, as in the case of the wheat land, so also in that of the barley land, there is, with the decline in the yield of nitrogen in the crop at the same time a decline in the stock of the nitrogen in the soil.

NITROGEN IN THE SOILS OF THE EXPERIMENTAL ROOT-CROP PLOTS.

The next results relate to the land upon which root crops—common turnips, swedes, sugar-beet, and mangel-wurzel—have (with the exception of the interpolation of three years of barley) been grown for forty years in succession, 1843–1882 inclusive. Samples of the soil have only been taken once, namely, in April, 1870; that is, after the experiment had been continued twenty-seven years. At that time 35 plots were sampled, and four samples were taken from each plot, each 6 by 6 inches area, and to a depth of 3 times 9 or 27 inches.

The following table shows the percentage of nitrogen in the surface soil of the continuously unmanured plot, and of three plots with mineral manure alone:

TABLE XI.—BARNFIELD ROOT-CROP LAND.

Nitrogen, per cent. in dry mold, first 9 inches.

[Root crops (except barley three years) forty years in succession, 1843–1882 inclusive.]

Kinds of manure.	1870.
	Per cent.
Plot 3.—Unmanured	0.0852
Plot 4.—Mixed mineral manure	0.0934
Plot 5.—Superphosphate alone	0.0888
Plot 6.—Superphosphate and potass	0.0867
Mean of plots 4, 5, and 6	0.0896

Having only taken samples once, we have, of course, no means of comparing the condition of the land as to its percentage of nitrogen at different periods. The point to be observed in the results given in the table is, that each of the four plots which have received no nitrogenous manure shows, after twenty-seven years of experiment (twenty-four years roots and three years barley), a lower percentage of nitrogen in the surface soil than has been found in any of the other experimental fields, though determinations made in samples from other parts of the same field, and also in an adjoining field, show considerably higher results. The nearest approach to so low an amount in any other field is where the land had been under alternate wheat and fallow for more than thirty years.

It will be remembered that the root crops gave with mineral manure alone a very much higher yield of nitrogen than the cereals in the earlier years and as low a yield in the later years. That they did not give less still is probably owing to the fact that their growth extends later in the season than the cereals, by virtue of which they are probably enabled to arrest the nitric acid formed within the soil during the autumn months, which in the case of the cereals would be more subject to loss by drainage.

Both the mechanical conditions of surface soil known to be favorable for the growth of the root crops, and the large amount of fibrous root they throw out near the surface, indicate an active demand on the resources of the upper layers of the soil, and are perfectly consistent with the supposition that their growth has led to a greater reduction in the stores of nitrogen of the superficial layers than in the case of any of the other crops.

The evidence afforded both by the facts of production and the determinations of nitrogen in the soil are indeed strongly in favor of the view that the source of the nitrogen of the root crops, as of the cereals, is, when grown without nitrogenous manure, the soil itself, and the small quantity of combined nitrogen annually contributed by rain, and the minor aqueous deposits from the atmosphere. It is said, however, that these crops require a certain amount of nitrogen to be supplied by manure, and that they then are able to take up the remainder from atmospheric sources. The facts of production recorded at page 7 afford no countenance to such a view. We conclude, indeed, that the dependence of these crops for their nitrogen, on the stores of the soil itself, or on supplies by manure, is as clearly established as in the case of the cereals.

IS THE SOIL A SOURCE OF THE NITROGEN OF THE LEGUMINOSÆ?

We have now to consider the bearing of the evidence on the question of the source of the nitrogen of the leguminosæ, and here we approach not only the most important but the most difficult part of our subject.

The first of the leguminous crops, the yield of nitrogen in which is recorded in Table I, is beans. Without manure the yield of nitrogen

was in the earlier years very much higher than with the cereals; but the decline was very great, and in the later years it was as low as with the cereals. With mixed mineral manure, including potass, the yield was throughout much higher, but the decline was, as without manure, very great. We have not a sufficiently comparative series of determinations of nitrogen in the soils of the bean plots, but such results as are at command lead to the conclusion that there has been a gradual decline in the percentage of nitrogen in the surface soils; but, considering the little tendency of the plant to throw out feeding root in the superficial layers, it may be a question how far the reduction is due to exhaustion by the direct action of growth, or how far to nitrification and passage of the nitrates downwards.

NITROGEN IN THE SOILS OF THE EXPERIMENTAL CLOVER-PLOTS.

The most important of the leguminous crops to which reference has been made is red clover. In Table I is recorded the yield of nitrogen over twenty-two years, in only six of which, however, was any crop obtained. The experiment has been continued with some modifications, and in 1877, that is after thirty years, in nine of the last ten trials the plant had died off during the winter and spring succeeding the sowing of the seed. Several small crops have since been obtained, and in March, 1881, samples of soil were taken from five places where no nitrogenous manure has been applied from the commencement, and at each place to three depths of 9 inches each. Exactly corresponding samples were also taken from an immediately adjoining plot, which had been thirty years under alternate wheat and fallow, without manure of any kind. The nitrogen was determined in each of the five separate samples, and also in the mixture of the five. Table XII summarizes the results.

TABLE XII.—HOOSFIELD CLOVER AND WHEAT AND FALLOW LAND.

Nitrogen, per cent. in dry mold, first 9 inches.

[Experiments more than thirty years.]

Mean.	1881.	
	Clover land.	Fallow land.
	Per cent.	*Per cent.*
Mean on five separate samples	0.1067	0.0925
Mean on mixture of five samples	0.1055	0.0984
Mean	0.1061	0.0955

It is true that the tendency of the evidence on the point is to show that red clover derives, at any rate, much of its nitrogen from the lower layers of the soil; but it is surely significant that, after the growth of heavy crops in 1849, when the land was in ordinary condition as to

manuring, and the constant failure since, there is coi
nearly as low a percentage of nitrogen in the surfac
nate wheat and fallow without manure. It is obvious
lation near the surface, due to residue from the small c
than compensated by exhaustion. The evidence oth
may be said to be of a somewhat negative charact
rate clear that failure of growth has been associate
and very low percentage of nitrogen in the surface s

The next results are of a very much more definite cha
to the two portions of the field which had grown six
cession by artificial manures alone, was then divide
one half clover and on the other half barley was grow
that in the clover crops 151.3 pounds, and in the barl
of nitrogen were removed. Yet in the next year, o
over both portions, the one which had yielded 151.
now yielded 69.4 pounds in barley; and the other,
only 37.3 in barley, now yielded only 39.1 pounds in

In October, 1873, after the clover and barley had
before the land was plowed up, samples of the soil
lows: From each portion four separate samples, eac
area and 9 inches deep, and the nitrogen was deter
rate sample and also in an equal mixture of the four.
each 6 by 6 by 9 inches, were also taken from each o
and the six samples representing each portion we
nitrogen determined in the mixture. At each p
separate samples were taken and mixtures made
spectively the second and the third 9 inches of
three and in many four determinations of nitrogen w
sample. The following table gives the mean resul
rate samples, the mean on the mixture of the four,
the mixture of the six:

TABLE XIII.—*Experimental clover and barley*

	Mean.
Mean on four separate samples (12 by 12 by 9)	
Mean on mixture of four samples (12 by 12 by 9)	
Mean on mixture of six samples (6 by 6 by 9)	
Means	

The accordance of the three sets of determinations
and for the barley land, respectively, can leave no d
there was a considerably higher percentage of nitrogen
of the clover ground than the same depth of the barl

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previous crops.

white clover roots beyond the surface soil. Whilst to the eye and to the hand the subsoil where the *metilotus* had grown was pumped dry, and was somewhat disintegrated, to the full depth sampled, that of the clover plot had no such character. Determinations in the soils and subsoils show at each of the six depths much less water in the *melilotus* than in the white-clover soils; and the difference is by far the greater in the lower depths. Calculated per acre, it would appear that to the depth of 54 inches the *melilotus* soil had lost approximately 450 tons more water per acre than the white-clover soil; and there can be no doubt that the pumping action had extended deeper still.

There is here, then, clear evidence that the plant whose habit of growth, and especially whose range and feeding capacity of root, suited it to the conditions, was enabled to take up much more water, and doubtless with it much more food, than, under exactly similar conditions of soil, were at the command of the plant of the much weaker development.

That the deep-rooting *melilotus* did derive more nitrogen from the subsoil than the shallow-rooting white clover is obvious from the following facts: Watery exhausts were made of each soil, at each depth, and the nitrogen as nitric acid determined in them.* The following table summarizes the results:

TABLE XIV.—*Nitrogen as nitric acid.*

	Per million, dry soil.		Per acre.		
	Melilotus soil.	White-clover soil.	Melilotus soil.	White-clover soil.	Difference.
			Pounds.	*Pounds.*	*Pounds.*
First 9 inches	1.25	3.19	3.33	8.42	5.09
Second 9 inches	0.35	1.07	0.95	2.89	1.94
Third 9 inches	0.20	0.64	0.56	1.79	1.23
Fourth 9 inches	0.31	1.00	0.96	2.99	2.03
Fifth 9 inches	0.27	1.40	0.84	4.38	3.54
Sixth 9 inches	0.53	1.69	1.65	5.31	3.66
Total			8.29	25.78	17.49

Thus the *melilotus* had not only exhausted the water, but the nitric acid of the soil at each depth very much more than the white clover had done, and the difference is especially marked at the lower depths. It is seen that in the case of the white-clover soil there is a diminishing amount of nitric acid from the first to the third depth, and then an increasing quantity to the sixth depth. It may fairly be supposed that there is greater concentration lower still, and that the exhausting action of the *melilotus* extended beyond the depth examined.

There is here direct evidence that the subsoil is the source of at any rate some of the excess of nitrogen of the *melilotus* over that in the white clover. The quantity and the distribution of nitric acid in the soil

*As nitric oxide, by its re-action with ferrous salts.

at any one time are so dependent on temporary conditions that it would be fallacious to attempt to estimate from the figures as they stand the exact amount which the *melilotus* has taken up more than the white clover. Then it is obvious that the action extended below the depth examined, and it is a question whether, with the greater disintegration and greater aeration, nitrification would not be favored in the lower depths, and if so the supply would be in a sense cumulative. Lastly, it may be that the deeply and widely distributed *melilotus* roots have the capacity of taking up nitrogen from the subsoil in other forms than as nitric acid.

NITROGEN AS NITRIC ACID IN OTHER SOILS AND SUBSOILS.

It will be some further aid in judging of the possibility or probability that the nitric acid in the soil and subsoil may be an adequate source of the nitrogen of the Leguminosæ, if we quote a few results indicating the amount of nitric acid found in soils under known conditions.

In the first place three soil drain-gauges, one with 20, one with 40, and one with 60 inches depth of soil, in its natural state of consolidation, and each of one-thousandth of an acre area, have been under experiment for between eleven and twelve years. No manure has been applied to these soils from the commencement; the drainage has been regularly collected and measured, and for nearly the whole of the last five years the nitric acid has been determined in monthly average samples of the drainage waters. Taking the result of the three gauges, for four harvest years (from September to August) these soils, which had been about six years without any manure at the commencement of the period under consideration, have lost by drainage an average of 42 pounds of nitrogen as nitric acid per acre per annum, of which perhaps not much more than 5 pounds would be due to rain and condensation of combined nitrogen from the atmosphere. In fact, from 30 to 35 pounds have been annually due to the nitrification of the nitrogenous matter of these unmanured soils. It has to be borne in mind, however, that the blocks of soil having access of air from below as well as from above, the nitrification may have been freer than it would be in soil in its ordinary condition.

Again, in some of the samples of soil taken from the plots in the experimental wheat field in October, 1865, and in many of those taken in October, 1881, that is in each case about two months after the removal of the crop, the nitric acid has been determined. In the case of one plot sampled in 1865, determinations made in 1866 (by Dr. Pugh's method) showed between 60 and 70 pounds of nitrogen as nitric acid per acre to the depth of 27 inches. In the samples of 1881 the amount of nitric acid found represented from under 30 to over 50 pounds of nitrogen per acre in that form, down to the depth of 27 inches, where ammonia and salts or nitrate had been applied for the previous crops. As in the case of the white-clover land, the amount decreased from the

first to the third 9 inches of depth from the surface, and if as in that case, it increased in the lower depths, we have evidence of a considerable store of nitric acid available for such plants as, by virtue of their habit of growth, are able to gather up the residue accumulated within the subsoil.

Determinations made in samples collected in the experimental rotation field in September, 1878, showed the following amounts of nitrogen as nitric acid per acre to the depth of 18 inches:

	With superphosphate only.	With full complex manure.
	Pounds.	*Pounds.*
After fallow	36.3	46.8
After beans	10.6	20.5
Difference	25.7	26.3

Samples collected at the same date from the unmanured alternate wheat and fallow plots showed to the same depth:

	Pounds.
After fallow	33.7
After wheat	2.6
Difference	31.1

Lastly, two fields which had been manured and cropped in the ordinary course of the farm, and had been fallowed since the previous autumn, showed the following amounts of nitrogen as nitric acid per acre to the depth of 27 inches:

	Pounds.
Clay croft field	58.8
Foster's field	56.5

It will be seen that in none of the cases cited is the amount of nitric acid found in the soils to the depth examined, sufficient to account for so large an accumulation in crop and in the surface soil as the figures relating to the nitrogen in the produce of clover, and in the clover and barley soil would indicate had been accumulated. The amounts of nitric acid formed, or remaining, within a limited depth from the surface, at any one time, is, however, as already intimated, dependent on so many temporary circumstances, that it is not to be expected that the amount formed within such limits at any given time would represent more than a fraction of that which would be available even within that range during the long period of growth of the clover crop. Then, the indications are that there is a considerable accumulation beyond the depth to which most of our examinations apply. And there still remains the question whether the roots of the plant do not take up nitrogen from the subsoil in other states than as nitric acid.

Finally in regard to the experiments with clover and barley, it is ad-

mitted that the various results of soil examinations which have been adduced do not conclusively show the source of the whole of the nitrogen to have been the soil. It will, we think, nevertheless be granted, that they do clearly point to the fact that at any rate much of it is derived from that source; whilst there is no evidence whatever of an atmospheric source of more than the small amount of combined nitrogen coming down in rain and the minor aqueous deposits, and the probably still smaller amount absorbed from the atmosphere by porous soil.

NITROGEN IN SOME OF THE SOILS OF THE EXPERIMENTAL MIXED HERBAGE PLOTS.

The results next to be referred to will afford additional evidence of the soil-source of the nitrogen of the Leguminosæ.

In Table 3 it was shown that in the mixed herbage of permanent grass land, without manure 33.0 pounds, and with a purely mineral manure (including potash) 55.6 pounds of nitrogen were yielded per acre per annum in the crop over a period of twenty years. Whence comes the 22.6 pounds more nitrogen per acre per annum taken up when the mineral manure was applied than without manure?

After twenty years of continuous experiment samples of soil were taken from three places on each plot, and in each case to the depth of six times 9 inches, or 54 inches. The mean results of the determinations of nitrogen in the surface soils are given in Table XV which follows:

TABLE XV.—EXPERIMENTS ON PERMANENT MEADOW LAND.

Nitrogen, per cent. in dry mold and per acre.

		1870.	1876.	1878.
		Per cent.	*Per cent.*	*Per cent.*
		0.2517	0.2466	.....
		.....	0.2236	0.2246
Difference		.....	0.0230	.....
			Pounds.	
Difference per acre..	Total twenty years	.....	506.0	.....
	Average per annum	.....	25.3	.....

Although we have not previously quoted the figures we have on several occasions stated in general terms that determinations of nitrogen in the soils show a lower amount in the mineral manured soil, approximately corresponding to the increased yield in the crop; and it is in reference to our statements on this point that M. Joulie has called in question the possibility of obtaining results of the kind applicable to our argument. He takes the fact of the increased yield of nitrogen under the influence of purely mineral manure as conclusive proof of the atmospheric source of the increased amount of nitrogen assimilated. He assumes that our calculations are based on determinations of nitrogen in a sample of the mixed soil to the total depth of 54 inches. He calculates that in the mass of soil to that depth the difference in the

amount in the two cases would be far too small to furnish a justification for the important conclusion that the soil was the source of the nitrogen; and he objects that the roots of such herbage would derive their nutriment chiefly in the superficial layers. He further objects that if the difference we assume were a fact, it is probably due to an accidental difference in the soil of the two plots, such a difference having been admitted by us in the case of another plot. Lastly, he suggests that if there really were the reduction we suppose, it might be due to other causes—such as increased activity of nitrification under the influence of the mineral manure and passage of the nitrates downwards.

In the first place, in the case of the irregularity in the condition of one of the plots referred to, the difference was readily seen in the section of the soil, and there was no such difference in the instance now under consideration.

Then it is the determination of nitrogen in the first 9 inches of soil alone, to which we have hitherto referred, and to which we confine attention on the present occasion.

In the next place, that the difference in the condition of the two plots is not merely local is shown by the fact that the determinations on a sample from the unmanured plot taken in 1870 entirely confirm the relative composition shown by the samples of 1876. Again, the lower percentage of nitrogen in the 1876 samples of the mineral manured plot is entirely confirmed by the results obtained on samples taken in 1878. Further, of the twenty experimental plots, there is only one other showing anything like so low a percentage as the mineral-manured plot, and that is the one which has received the same mineral manure, but for a shorter series of years.

We have in fact no doubt whatever that the differences shown by the figures are real and dependent on the conditions of manuring and of growth. The reduction is, moreover, very great, amounting to nearly one-tenth of the total quantity of nitrogen, an amount far beyond the limits of accidental difference in the sampling or the analysis.

Calculated per acre, the surface soil of the mineral-manured plot contained, at the end of the twenty years, 506 pounds less nitrogen than the soil of the unmanured plot to the same depth, corresponding to an annual reduction of 25.3 pounds of nitrogen per acre per annum. It is, to say the least, a very remarkable coincidence that the increased yield of nitrogen on the mineral-manured plot which has to be accounted for is 22.6 pounds per acre per annum.

We do not pretend to claim absolute accuracy for such results, but we ourselves entertain no doubt whatever of their significance and their importance. It will be asked, How is it that in the case of the red clover and the *melilotus* it was concluded that, so far as the plants had derived their nitrogen from the soil, it was at any rate mainly from the lower depths, and that here we assume the increased yield of nitrogen to be derived from the surface soil?

Under the influence of the mineral manure a larger proportion and

amount of leguminous herbage was developed than on any other plot, but the leguminous plant the most and indeed very prominently favored was the *Lathyrus pratensis*, which throws out an enormous quantity of root near the surface; and it is sufficiently established that the potash of artificial manures remains almost exclusively in the superficial layers. On the other hand, the perennial red clover and the *Lotus corniculatus*, which have a much more deeply-rooting tendency, are comparatively little encouraged. The actual amount of leguminous herbage produced, however, is not sufficient to account for nearly the whole of the increased yield of nitrogen in the produce of the plot. The fact is that besides a proportionately very large increase in the growth of leguminous herbage, there has been a gradually increasing amount of gramineous produce developed; far beyond what would be anticipated from the extremely limited effect of such manures on gramineous crops grown separately on arable land. How far this result may be due to the much more active nitrification induced under the influence of the mineral manure in the much more highly nitrogenous grass land than in the poorer arable soil, and so yielding a direct supply to the graminæ of the mixed herbage, or how far to an increased supply in a condition available for the grasses as the result of the increased growth of the Leguminosæ, may be a question. But it is of interest to note that the gramineous species that are developed are among the most superficially rooting of the grasses found on the experimental plots.

Before leaving the subject of these experiments on the mixed herbage of grass land, it may be well to call attention to the fact that, on the assumption that the whole of the nitrogen of the herbage, beyond the small amount of already combined nitrogen contributed by rain and condensation from the atmosphere, is derived from the soil, we have to conclude that about .25 pounds per acre per annum have been yielded by the soil of the unmanured plots, and nearly an additional 25 pounds, or in all about 50 pounds, from the mineral-manured plot. It was estimated that, in the case of the continuous wheat experiments, about 20 pounds of nitrogen had been annually obtained in the crop, and a minimum of 12 pounds lost by drainage; in all 32 pounds. It cannot fail to be observed how closely this amount corresponds with the annual yield of nitrogen in the unmanured mixed herbage. With the richer grass land, though less aerated than arable land, it might be expected there would be some increased activity of nitrification, even in the unmanured soil, and there may be some loss by drainage; but, with a mixed herbage of some 50 species of very varying habit of growth, and with the possession of the soil all the year round, it is only what would be expected that there would be more of the available nitrogen taken up by the crop and less lost by drainage than with the cereal grown separately on arable land, and occupying the soil for only a very limited period of the year.

We conclude, then, that the results relating to the two mixed herbage

plots can leave little doubt that the increased yield of nitrogen in the more highly leguminous produce of the mineral-manured plot had its source in the stores of the soil itself.

SOURCE OF THE NITROGEN OF CLOVER GROWN ON RICH GARDEN SOIL.

We have one more illustration to bring forward having an important bearing on the question at issue.

In view of the signal failure in the attempt to grow red clover on a nitrogen exhausted arable soil, it is of much interest that large, though declining, crops have been grown for twenty-nine years in succession on a plot of rich kitchen-garden soil.

The experiment was commenced in 1854, and the following table shows the percentage of nitrogen in samples of the first 9 inches of soil taken in October, 1857, and in May, 1879; that is, with an interval of twenty-one seasons of growth. In 1857 only one sample was taken, and only to the depth of 9 inches, but in 1879 three samples were taken, in each case to the depth of twice 9, or 18 inches:

TABLE XVI.—CLOVER GROWN ON KITCHEN-GARDEN SOIL.

Nitrogen, per cent. in dry mold and per acre.

	1857.	1879.	Difference.
	Per cent.	*Per cent.*	*Per cent*
	.....	0.3635	.....
	.....	0.3640	.....
	.....	0.3626	.....
	0.5095	0.3634	0.146
	Pounds.	*Pounds.*	*Pounds*
Per acre, total	10.190	7.268	2.922
Difference per acre per annum	.....	.....	0.139

The percentage of nitrogen given for the single sample collected in October, 1857, is the mean of determinations made in 1857, 1866, and 1880, and is almost identical with the mean of those made at the latest date. The first point to observe is that the first 9 inches of the garden ground contained more than half a per cent. of nitrogen, about four times as much as the average of the arable soils, and nearly five times as much as the exhausted clover-land soil. It is of course true that the soil would be correspondingly rich in all other constituents; but some portions of the arable soil where clover failed, had received much more of mineral constituents by manure than had been received in the crops.

The means of the determinations made on the three separate samples taken in 1879 agree very well, and the results can leave no doubt whatever that there has been a great reduction in the stock of nitrogen in the surface soil. The reduction amounts to about 29 per cent. of the total, and, reckoned per acre, as shown at the foot of the table, it corresponds to a loss of 2.922 pounds during the twenty-one seasons of growth; and although really good crops are still grown in most years there has been, with this great reduction of the stock of nitrogen in the soil, a very marked reduction in the clover-growing capability of the

soil. Thus, during the first fourteen of the twenty-nine years of the experiment, seed was sown only three times, whilst during the last fifteen years it has been necessary to sow ten times. It is obvious, therefore, that the plant stood very much longer during the earlier than the later years. Then, again, the produce from the three sowings during the first fourteen years was nearly twice as much as has been obtained since.

The question obviously arises, what relation does the amount of nitrogen lost by the soil bear to the amount taken off in the crops? We quite admit the uncertainty of calculations of produce per acre from the results obtained on a few square yards. We are, however, disposed to estimate the average yield of nitrogen over the twenty-one years at about 200 pounds per acre per annum. The table shows that against this we have an estimated loss of nitrogen by the first 9 inches of soil of 139, say 140, pounds per acre per annum, corresponding approximately to three-fourths of the amount estimated in the crop.

There is, however, evidence leading to the conclusion that, at any rate in the case of arable soils containing an unusually high percentage of nitrogenous organic matter, there may be a loss by evolution as free nitrogen; and, obviously, so far as this may have occurred in the garden soil, there will be the less of the determined loss to be credited to assimilation by the growing clover. On the other hand, it is known that when growing on ordinary arable soil, the clover plant throws out a large amount of roots in the lower layers, and although in the case of so rich a surface soil, the plant may derive a larger proportion of its nutriment from that source, we must at the same time suppose that it has also availed itself of the resources of the subsoil. Unfortunately, we did not sample deeper than 9 inches in 1857, so that we can make no comparison of the condition of the subsoil at the two periods. It may, however, be observed that in 1879 the second 9 inches showed about three times as high a percentage as the subsoils of the arable fields at the same depth; indeed, not far from twice as high a percentage as several of the exhausted arable surface soils. It cannot be doubted, therefore, that the subsoil of the garden plot has contributed to the yield of nitrogen in the crop.

If, then, we have not here absolute proof that the source of the whole of the nitrogen of clover growing on the garden soil was the soil itself, we have surely very strong grounds for concluding that much of it has been so derived.

GENERAL CONCLUSIONS.

In fact, after this review of the evidence which the determinations of nitrogen in the soils of our experimental plots afford, we end, as we began, by saying that, although we admit the facts of production are not yet conclusively explained, we maintain that there is, to say the least, much more of direct experimental proof of the soil than of the atmospheric source of the nitrogen. Moreover, we submit that this

may be said not only of the source of the nitrogen of the cereals, but of the root crops and of the Leguminosæ.

If, on the other hand, the atmosphere is the main, if not the exclusive, source of the nitrogen of the Leguminosæ, we would ask here, as we have asked elsewhere, why those leguminous crops which take up the most nitrogen can be less frequently grown on the same soil? Why we entirely failed to grow clover successively on ordinary arable land, which was nevertheless in a condition to yield fairly good corn crops? Why the only condition under which we have been able to grow clover continuously was where the soil was very much richer in nitrogen (and of course in other constituents also) than the arable land? And lastly, why its growth under such circumstances has been accompanied by a rapid diminution in the amount of nitrogen in the soil, and with this a marked decline in the produce?

It will not for a moment be supposed that because in the foregoing illustrations and arguments we have confined attention almost exclusively to the nitrogen in the soils, we in any way ignore the importance of a liberal available supply of the mineral constituents, so essential for the effective action of the nitrogen. There is abundant evidence, however, that the failures that have been cited have not been due to a deficiency of such constituents.

If, then, the supply of mineral constituents not being defective, the yield of our crops is in the main dependent on the amount of nitrogen which is available to them within the period of their growth, surely the fertility of a soil must be largely measured by the amount of nitrogen it contains and the degree in which it becomes available. And if this be so, is not the soil a mine as well as a laboratory?

In this connection, speaking here in America, it will not be inappropriate to conclude with a brief reference, such as the limited data at our command will permit, to what we believe must be a characteristic difference between the comparatively recently or even not yet broken up soils of this continent, and those which have been long under arable culture on the other side of the Atlantic.

A sample of Illinois soil obtained some years ago by Mr. (now Sir) James Caird, and submitted by him for analysis to Dr. Voelcker, to whom we are indebted, not only for his own analytical results, but also for a sample of the soil itself, shows, by almost identical results in the two laboratories, very nearly 0.25 per cent. of nitrogen. We have no history of this soil, nor do we know the depth to which it was taken, but Dr. Voelcker informs us that the sample supplied to us was a mixture of both soil and subsoil as supplied to him, and in the separate surface soil he found 0.33 per cent. of nitrogen.

During the present year between forty and fifty samples of soil from the Northwest Territory, taken at intervals between Winnipeg and the Rocky Mountains, were sent over to the High Commissioner in London, and exhibited at the recent show of the Royal Agricultural Society

of England, at Reading. The soils were exhibited in glass tubs 4 feet in length, and are stated to represent the core of soil and subsoil to that depth. Three samples of the surface soils have kindly been supplied to us for the determination of the nitrogen in them:

No. 1 is from Portage le Prairie, about 60 miles from Winnipeg, and has probably been under cultivation for several years. The dry mold contained 0.2471 per cent. of nitrogen.

No. 2 is from the Saskatchewan district, about 140 miles from Winnipeg, and has probably been under cultivation a shorter time than No. 1. The dry mold contained 0.3027 per cent. of nitrogen.

No. 3 is from a spot about 40 miles from Fort Ellis, and may be considered a virgin soil. The dry mold contained 0.2500 per cent. of nitrogen.

In general terms it may be said that these Illinois and Northwest Territory surface soils are more than twice as rich in nitrogen as the average of the Rothamsted arable surface soils, and, so far as can be judged, probably twice as rich as the average of arable soils in Great Britain. They indeed correspond in this respect very closely with the surface soils of our permanent pasture land. As this nitrogen has its source in the accumulation from ages of natural vegetation, with little or no removal, it is to be supposed that, as a rule, there will not be a relative deficiency of the necessary mineral constituents. Surely, then, these new soils are mines as well as laboratories! If not, what is the meaning of the term *a fertile soil*?

But, assuming these soils not to be deficient in the necessary mineral supplies, and that they yield up annually in an available condition an amount of nitrogen at all corresponding to their richness in that constituent, it may be asked whether they should not yield a higher average produce of wheat per acre than they are reported to do? The exhausted experimental wheat field at Rothamsted, the surface soil of which at the commencement of the experiments thirty-nine years ago probably contained scarcely half as high a percentage of nitrogen as the average of these four American soils, yielded over the first eight years 17½; over the next fifteen years, 15¼; over the last fifteen years (including several very bad seasons), only 11⅛ bushels; and over the whole thirty-eight years about 14 bushels per acre per annum. So far as we are informed, the comparatively low average yield of the rich Northwest soils is largely due to vicissitudes of climate, but largely, also, to the luxuriant growth of weeds, which neither the time at command for cultivation nor the amount of labor available render it easy to keep down. Still, if there be any truth in the views we have advocated, it would seem it should be an object of consideration to avoid, as far as practicable, this great source of reduction of the fertility of these now rich soils.

Report #32

DEPARTMENT OF AGRICULTURE.

THE AGRICULTURAL GRASSES

OF THE

UNITED STATES,

BY

DR. GEORGE VASEY,
BOTANIST OF THE DEPARTMENT OF AGRICULTURE

ALSO

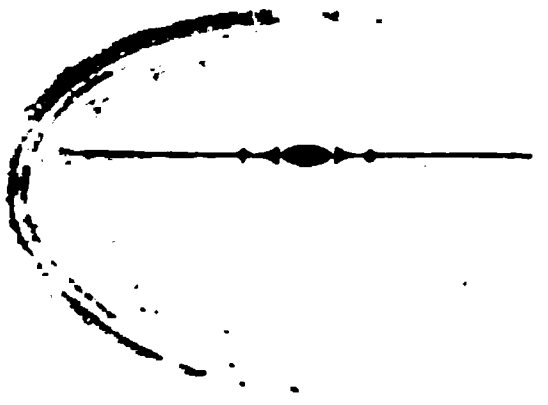
THE CHEMICAL COMPOSITION

OF

AMERICAN GRASSES,

BY

CLIFFORD RICHARDSON,
ASSISTANT CHEMIST.



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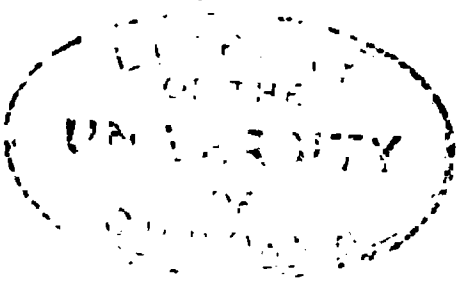

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1884.

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WASHINGTON, D. C., *July* 1, 1884.

SIR: I herewith submit a special report on the grasses of the United States which are either native or naturalized and which have more or less agricultural value.

Respectfully yours,

GEO. VASEY,
Botanist of the Department.

HON. GEORGE B. LORING,
Commissioner.

[redacted]

U C

REPORT.

Every thoughtful farmer realizes the importance of the production on his land of a good supply of grass for pasturage and hay. He, who can produce the greatest yield on a given number of acres, will be the most successful man; yet this is a subject which has been, and still is, greatly neglected.

In the United States we have many climates, many kinds of soil, many geological formations, many degrees of aridity and moisture. It must be apparent that one species of grass cannot be equally well adapted to growth in all parts of this extensive territory; yet hardly a dozen species of grasses have been successfully introduced into our agriculture. True it is that this number answers with a tolerable degree of satisfaction the wants of quite an extensive portion of the country, chiefly the northern and cooler regions. But it is well known that in other localities the same kinds of grasses do not succeed equally well, and one of the most important questions for those regions is to obtain such kinds as shall be thoroughly adapted to their peculiarities of climate and soil. This is particularly the case in the Southern and Southwestern States, the arid districts of the West, and in California.

The solution of this question is largely a matter of experiment and observation.

The grasses which we have in cultivation were once wild grasses, and are still such in their native homes.

The question then arises, can we not select from our wild or native species some kinds which will be adapted to cultivation in those portions of the country which are not yet provided with suitable kinds? Many observations and some experiments in this direction have already been made, and if proper research is continued, and sufficiently thorough experiments are followed up, there is no reason to doubt that proper kinds will be found for successful cultivation in all parts of the country.

GRASSES OF THE GREAT PLAINS.

The plains lying west of the one hundredth meridian, together with much broken and mountainous interior country, nearly treeless and arid, in New Mexico, Western Texas, and Arizona, are nearly useless for the purposes of ordinary agriculture, but are becoming more and more important as the great feeding ground for the multitudes of cattle which supply the wants of the settled regions of our country, as well as the constantly increasing foreign demand. The pasturage of this region consists essentially of native grasses, some of which have acquired a

wide reputation for their rich nutritious properties, for their ability to withstand the dry seasons, and for the quality of self-drying or curing, so as to be available for pasturage in the winter. This quality is due probably to the nature of the grasses themselves and to the effect of the arid climate. It is well known that in moist countries, at lower altitudes, the grasses have much succulence; they grow rapidly, and their tissues are soft; a severe frost checks or kills their growth, and chemical changes immediately occur which result in rapid decay; whereas in the arid climate of the plains the grasses have much less succulence, the foliage being more rigid and dry, and therefore when their growth is arrested by frost the tissues are not engorged with water, the desiccating influence of the climate prevents decay, and the grass is kept on the ground in good condition for winter forage. General Benjamin Alvord, of the United States Army, has recently published an article on the subject of these winter-cured grasses, and states that they only acquire this property on land which is 3,000 feet above the level of the sea. The region having such an altitude includes, he says, all, nearly up to the timber-line, of Montana, Idaho, Wyoming, Utah, Nevada, Colorado, and New Mexico; five-sixths of Arizona, one-half of Dakota, one-fourth of Texas, one-fifth of Kansas, and one-sixth each of California, Oregon, and Washington Territory, embracing about one-fourth of the area of the whole United States.

Many of the grasses of this extensive region are popularly known as "bunch grass," from their habit of growth; others are known as "mesquite" and "gramma grass." These consist of many species of different genera, some of them more or less local and sparingly distributed, others having a wide range from Mexico to British America.

The most important of the "bunch grasses" may be briefly mentioned as follows: Of the genus *Stipa* there are several species; *Stipa comata* and *Stipa setigera* occur abundantly in New Mexico, Texas, Arizona, and California, reaching to Oregon. In Colorado, Kansas, and all the prairie region northward, stretching into British America, *Stipa juncea* is the principal one of the genus. On the higher plateaus and near the mountains the *Stipa viridula* is very common, extending from Arizona to Oregon and British America. Somewhat related botanically is *Eriocoma cuspidata*, a very rigid bunch grass, with a fine, handsome panicle of flowers. It is equally widespread with the preceding. Another widely diffused grass is *Aira cæspitosa*, varying much in size and thriftiness according to the altitude and amount of moisture where it grows, but always having a light, elegant spreading panicle of silvery-gray flowers.

One of the most extensively diffused grasses is *Kœleria cristata*, varying in height from to 1 foot to 2½ feet, with a narrow and closely-flowered spike. Several species of fescue grass (*Festuca*) are intermixed with the vegetation in varying proportions; the most important of these, probably, are *Festuca ovina* in several varieties, and

Festuca scabrella, the latter especially in California, Oregon, and Washington.

The genus *Calamagrostis* (or *Deyeuxia*, as it is now called) furnishes several species which contribute largely to the vegetation of this region. They are mostly tall, stiff, and coarse grasses, but leafy and some of them very nutritious. Of these *Deyeuxia sylvatica* and *Deyeuxia stricta* are the least valuable. Perhaps the best of them is *Deyeuxia canadensis*, which is soft and leafy. Next in value, probably, is *Deyeuxia aleutica* of California and Oregon, extending into Alaska. *Calamagrostis* (*Ammophila*) *longifolia*, confined chiefly to the plains east of the Rocky Mountains, is tall and reed-like, growing in dense clumps, from 4 to 6 feet high.

Several species of *Andropogon* are diffused from Arizona to British America, but are not found on the western coast. The principal species are *Andropogon scoparius*, *A. furcatus* and *A.* (*Chrysopogon*) *nutans*. Some of them are known under the name of blue-joint.

Other grasses also widely spread, but in more sparing quantity are several species of *Poa* and *Glyceria*. Several varieties of *Triticum* (*Agropyrum*) *repeus*, or Couch grass, occur abundantly in saline soils, and also *Agropyrum glaucum*, which is widely known as blue-stem and is considered among the most nutritious of grasses. *Brizopyrum spicatum* now called *Distichlis maritima*, and some species of *Sporobolus*, also form extensive patches or meadows in saline soils. Besides, there is a large number of grasses of low growth and of more spreading habit, which are known in the southwest and east of the Rocky Mountains under the names of mesquite and buffalo grasses. The former belong mostly to the genus *Bouteloua*, the most important species being *B. racemosa* or tall mesquite, and *B. oligostachya* or low mesquite. The true buffalo grass is botanically *Buchloë dactyloides*, which in many places forms extensive fields or areas. It is of a low and densely-tufted or matted habit. Another similar grass, spreading out in low, wide patches is *Munroa squorrosa*. The above-mentioned species form the larger proportion of the grassy vegetation of the great plains.

GRASSES OF MONTANA.

Prof. F. L. Scriber, of Girard College, Philadelphia, an accomplished botanist, spent the past summer in Montana in an investigation of the agricultural capabilities of the country, and he has furnished some valuable notes on the grasses of that region, from which we give the following selections:

"*Beckmannia erucæformis*.—Grows along the wet banks of streams, rivers, and irrigating ditches, never away from a constant and abundant supply of water. In favorable localities it attains the height of 3 feet, and yields an abundance of tender herbage. Well adapted for cultivation.

"*Hierochloa borealis*.—Common along the streams and rivers in the

mountainous districts, frequently occupying extensive areas to the exclusion of all other grasses.

"*Alopecurus glaucus.*—Very common along mountain streams and frequently covering acres of the so-called mountain meadows. Its slender but leafy culms grow to the height of 3 feet or more, and it is called in some localities 'native timothy,' which it resembles in habit. It yields to the acre a great bulk of fine, long, bright-colored hay, for which purpose it is often harvested and highly valued. It has little value for grazing. It grows most luxuriantly between the altitudes of 5,000 and 6,000 feet. Under cultivation I see no reason why this grass should not become as celebrated on the great western plateau as is its near relative, the meadow foxtail, in the moist climate of England.

"*Stipa comata.*—Common on the bench lands, growing in soil too gravelly and thin for *Poa tenuifolia*. In richer soil it grows tall and produces a great abundance of forage.

"*Stipa viridula.*—This is the most valuable of the *Stipas*, growing in light, sandy loam, frequently covering large areas to the exclusion of other species. In favorable localities it attains the height of 3 feet. The associated species are *Stipa comata*, *Poa tenuifolia*, and *Kœleria cristata*.

"*Eriocoma* (*Oryzopsis*) *cuspidata*, abundant on the lower sandy bench lands bordering the Missouri. It is one of the esteemed 'bunch grasses' and thrives on soil too sandy for other valuable species.

"*Phleum alpinum*, called 'native timothy;' it grows in mountainous regions near streams, ascending to the altitude of seven or eight thousand feet. At elevations between five and six thousand feet I have seen this grass growing in rich open woods along with common timothy (*Phleum pratense*), and it was the more luxuriant of the two—not so tall, perhaps, but growing to the height of 2 feet, with larger and more leafy culms. I see no reason why, in the region where this grass grows naturally in such luxuriance, it may not take the place in cultivation of the well-known and justly valued timothy of the East.

"*Agrostis exarata.*—Grows only along the rich, moist banks of streams in the mountain districts. Apparently a valuable grass to introduce into cultivation.

"*Deyeuxia Canadensis.*—Common along streams. There is a species allied to *Deyeuxia neglecta*, perhaps only a variety of it, that grows upon the dry bench lands along with *Poa tenuifolia* and *Koeleria cristata*, and so closely resembling the latter in habit that at a little distance it is difficult to distinguish the one from the other.

"*Deschampsia cæspitosa* is common in moist meadows even when the soil is highly alkaline. It yields an abundant growth of stalks and leaves, and may have some value, but it is not recognized as a forage plant.

"*Bouteloua oligostachya*, the 'buffalo grass,' of Montana. Abundant on the lower benches at elevations of from 3,000 to 4,500 feet, and

regarded as one of the most valuable of the forage grasses. It stands tramping better than any other species, and comes in when other species have been tramped out. Its fine, curly leaves make a dense turf of highly nutritious herbage. The true buffalo grass (*Buchloë*) was not seen.

"*Kæleria cristata*, called 'June grass,' is very common on the bench lands, disputing possession with *Poa tenuifolia*. These two may be said to be the most common grasses of the low districts.

"*Distichlis maritima*, or 'salt grass,' is common in alkaline soil along the rivers. It is of little or no value for forage, and considered a great nuisance in agriculture, as its tough and matted roots form a sod that is almost impossible to be broken up.

"*Poa*.—All the *Poas*, wherever growing in abundance, yield much excellent food for stock. On the mountain tops we find *Poa alpina*, *Poa laxa*, and *Poa cæsia*. *Poa Neradensis* is common along mountain streams, and on the slopes we find *Poa serotina* and *Poa nemoralis*. *Poa pratensis* is truly indigenous, and grows abundantly along the streams and rivers. *Poa tenuifolia*, in its various forms, may be called *the* grass of the country. It constitutes the chief forage upon the dryest bench lands, where it is called 'bunch grass,' or, on account of its reddish color, 'red-top.' Another local name is 'red-topped buffalo grass.' In dry situations its culms are low and slender, and the foliage is confined to the dense radical tuft, the leaves of the stem being very short and of little account. When growing in rich soil, along streams or on land naturally irrigated, it makes a luxuriant growth of stems and foliage 2 to 6 feet high; and a field of *Poa tenuifolia* in bloom presents as fine an appearance as does a field of Kentucky blue grass in the East, and the produce per acre, I should think, nearly the same. This and *Kæleri cristata* are usually associated, and both bloom about the same time, June 15 to 30. As fine a field of natural grasses as I saw in Montana contained *Poa tenuifolia*, *Kæleria cristata*, *Stipa viridula*, and *Stipa comata* as the leading species, the *Poa* being the most abundant. In this field the *Stipas* were unusually fine, overtopping the other grasses.

"*Festuca scabrella*, the 'great bunch grass' and 'buffalo bunch grass,' is one of the principal grasses of the country. It is the prevailing species on the foot-hills and mountain slopes at from six to seven thousand feet. In respect to elevation above the sea, the following is the order of the most important grasses of the grazing lands of Montana: *Bouteloua oligostachya*, *Poa tenuifolia*, *Kæleria cristata*, and *Agropyrum glaucum* occupy the low lands and benches; then *Agropyrum divergens;* above this is *Festuca ovina, var.*, and above all comes *Festuca scabrella*. In any of the mountain valleys the belts of altitude occupied by these grasses are well defined: First and lowest, *Poa tenuifolia* prevails; between this and *Festuca ovina* there is usually, though not always, a belt of *Agropyrum divergens*. Usually, at about 6,000 feet, *Festuca ovina* gives way to *Festuca scabrella*. The latter may be regarded as the more abundant

and valuable species of the two. It is rather too hard a grass for sheep, but there is no more valuable grass on the 'summer ranges' for cattle and horses. It makes excellent hay for horses, and is cut in large quantities for this purpose. It grows in large tussocks, making it rather a difficult grass to mow with a machine. *Festuca ovina, var.* prevails in the mountain regions on a line of altitude just below *Festuca scabrella*, growing in close bunches, and yields a large amount of forage for all kinds of stock.

"*Agropyrum glaucum*, 'blue-joint' and 'blue-stem,' is the most highly praised of the native grasses for hay. Wherever this grass occupies exclusively any large area of ground, as it frequently does in the lower districts, especially near Fort Benton, it is cut for hay. Naturally, it does not yield a great bulk, but its quality is unsurpassed. It has a tough, creeping root, like the 'couch grass' of the Eastern States, and by some is regarded as a variety of it. After two or three cuttings the yield of hay diminishes so much that it is scarcely worth the harvesting. An effectual way to increase the stand of grass after a succession of cuttings, as proved by actual experiment, is to drag over the sod a short-toothed harrow, which breaks up the roots or underground stems, and each fragment of root then makes a new plant.

"*Hordeum jubatum*, or 'fox-tail grass,' is common on the low lands, especially where there is moisture. It is looked upon as one of the worst of weeds. Its presence with other grasses destroys their value entirely for hay.

"*Elymus condensatus*, or 'wild-rye grass,' is the only species that is known popularly. It grows along the streams and rivers, often covering extensive areas. It is valued chiefly as a winter forage grass. It yields a great bulk of coarse hay, but is rarely harvested. When growing in fields of 'blue-joint' the blue-joint is cut and the rye grass is left standing. If cut before flowering it makes a good hay, but if left until it comes into flower, it is not only too hard for hay, but is too hard to cut, except with a bush-scythe."

In connection with this subject the question arises, what effect will continued pasturage have upon the perpetuity of the grasses composing these great pasture-fields? Probably in the course of time certain species will disappear, being unable to withstand the constant tramping and cropping by cattle and sheep, and it will be necessary to fill their place with more hardy species. If this is not done by self-propagation it will then become necessary for the proprietors of the land to make selection from the native species which prove hardy, or to seek out suitable species from other countries. It can hardly be doubted that among our very many native species there are those which will meet the requirements of the occasion, but much careful observation and many trials and experiments will need to be made before the question is satisfactorily determined. To an intelligent performance of this work a knowledge is first required of the characteristics, habits, and names of

the species now occupying the ground, and a very important aid to the acquisition of this knowledge will be found in the present work, with its descriptions and figures of a large number of the common grasses now prevailing in different parts of the country. A careful study of these and comparison with the living plants will enable an ordinary observer to identify the grasses which may come under his observation.

A chapter is also presented on the structure and characteristics of grasses in general, their various organs and parts, and the technical terms by which they are distinguished.

Where the species of a genus or order of plants are so numerous and so closely related as they are in the case of the grasses it is impossible, without an immense repetition of words, to describe accurately the differences between different kinds by the use of popular language. Any one, therefore, who may wish to obtain an accurate acquaintance with them will find it necessary to learn something of the botanical terms used in describing plants. We hope, therefore, that the reader will not be dismayed by the use of the technical descriptions, but will consult the glossary, where the terms are explained.

Among the younger readers, and especially, we may hope, among agricultural students, there are many who will be glad to have precise and scientific descriptions, for this is an age of progress, and an age when even the labor of the farm may be enlivened and beautified by mental improvement and by a scientific knowledge of the common objects of life.

For a close study of the flowers of grasses a small magnifier or lens, single or double, will be needed. One magnifying five to ten diameters will be sufficient, and such a one can generally be purchased at a jeweler's for a dollar or two.

Within the limits of the United States there are about six hundred species of grasses, mostly native, a few naturalized from other countries. Many of these species are either too small, too coarse, too sparse, or in some other way wanting in the character needed for a good agricultural grass. But it is certain that among this great number there are some which will be found suitable for cultivation at least in special districts. We have here selected from all parts of the country about one hundred and twenty species for description and illustration.

GENERAL REMARKS ON GRASSES.

The name grass in popular usage is by no means a definite term, as it is often applied to plants which have no botanical relationship. In a popular sense it includes the sedges, rushes, various plants with grass-like leaves, and sometimes such widely different plants as clover. On the other hand, many persons will be surprised on being informed that all the cereals, as wheat, barley, rye, oats, sugar-cane, sorghum, Indian corn, rice, and bamboo are true grasses. In this paper, however, we consider mainly such grasses as are used for pastures, meadows, or fodder purposes, or which have some importance in that direction.

GENERAL DESCRIPTION OF GRASSES.

A grass possesses the following parts: (1) the root, (2) the culm, (3) the leaves, (4) the flowers.

(1.) The roots are the fibrous ramifications which extend downward into the ground and appropriate the water or other liquid nutriment to be conveyed into the stem and leaves.

(2.) The stem or *culm* is the ascending part which commonly rises above ground, either erect or reclining. Sometimes the culm is horizontal and subterranean, sending out erect branches and fibrous roots at the joints. These are called creeping stems, or, improperly, creeping roots. They are botanically called rhizomes, and sometimes are several feet long. In some grasses there is a kind of bulb at the base of the stem, in which is stored a concentration of nutriment for the support of the plant under peculiar circumstances, as in protracted drought. This bulbous formation is a part of the stem, and not of the root. The stem or culm of grasses is usually cylindrical and hollow; sometimes it is more or less compressed or flattened. It is divided at intervals by transverse thickened portions called joints or nodes, at which points leaves and sometimes branches are given off. These nodes tend also to strengthen the stem. Stems are usually simple and unbranched, except at the top, where they commonly divide into the more or less numerous branches of the panicle or flowering part. But some stems give rise from the side joints to leafy branches, which may, like the main stem, produce smaller panicles at the top.

(3.) The leaves take their origin at the nodes or joints in two ranks—that is, they are placed alternately on opposite sides of the stem at greater or less distances—thus, the first leaf will be on one side, the second on the opposite side a little higher up, the third still higher and directly over the first, the fourth over the second, and so on. The leaves consist of three parts: (1) the *sheath*, (2) the *ligule*, and (3) the *blade*. The *sheath* is that part which clasps the stem. It is generally open on one side, as will be readily observed in the leaves of a corn-stalk, but in some grasses the sheath is partly or even completely closed together by the adhesion of the opposite edges. The sheath is analogous to the stem or petiole of the leaves of many higher plants. The *ligule:* At the point where the blade of the leaf leaves the stem, at the top of the sheath and on the inner side, there is usually a small, thin, leaf-like organ, called the ligule or tongue. This is sometimes half an inch long, more commonly only two or three lines, and sometimes it is almost absent or reduced to a short ring, but its length and size is very constant in the same species. This ligule represents the stipules which occur at the base of the leaves in many of the higher plants. The *blade* or *lamina* of the leaf is the expanded part which is commonly called leaf. In the majority of grasses the leaf is long and narrow; that is, many times longer than wide. There is one central nerve, called

midnerve or *midrib*, extending to the point of the leaf, and numerous lines or *nerves* on each side running parallel to each other, and not nected by transverse nerves and not giving off branches as in the her plants. These leaves are in some species rough, in others oth, hairy, or downy, &c. The agricultural value of a grass depends inly upon the quantity, quality, size, and nutritive properties of the es.

4.) The flowers: The flowers of the grasses are generally at the end he stem or the side branches, sometimes very few in number, some- es in great abundance, sometimes in a close *spike*, and sometimes in *anicle*, with many spreading branches or *rays*. The flowers may be gle on the branches or on the *pedicels*, or they may be variously clus- d. In the common red-top (*Agrostis alba* or *A. vulgaris*), there is a gle flower at the end of each of the small branchlets of the panicle. h of these flowers is inclosed by a pair of small leaf-like scales or ff, called the outer or empty *glumes*. The flower consists of (1) the ntial organs and (2) the envelopes. The essential organs are the *nens* and *pistils*, which may readily be seen when the grass is in om. The stamens, of which there are usually three in each flower, sist of the *anther* and *filament*, the anther being the small organ ch contains the *pollen* or dust which fertilizes the pistil or female an, and the filament being the thread-like stem on which the anthers borne.

he *pistil* is the central organ of the flower, and consists of three ts, the *ovary*, the *style*, and the *stigmas*. In most of the grasses the les are divided into two branches which have a handsome plumose earance. The *stigmas* are the delicate parts at the extremity of se branches which receive the *pollen* for the fertilization of the flower, the *ovary* is that part at the base which contains the future seed. he envelopes of the flower are usually two leaf-like scales or husks in- sing between them the *stamens* and *pistil*; these scales face each other, being a very little higher on the axis than the other, and also ally smaller and more delicate in texture. This smaller scale is called *palet*; the other larger and usually coarser one is called the *flower- glume*; its edges generally overlap and partly inclose the palet. he *flower* constituted as above described, together with the pair of er or *empty glumes* at the base, form what is called a *spikelet*. In ny cases, however, there are two three, or more flowers, sometimes en ten to twenty, in one spikelet, in which case they are arranged lternately on opposite sides of the axis, one above the other, with a air of empty or outer glumes at the base of the cluster. Such may be een in the blue grass (Poa pratensis), fescue grass (Festuca), and many thers.

There are innumerable modifications of these floral organs, and upon he differences which exist in them the distinction of genera and species re based. In some cases the glumes are entire in outline, in some they

are toothed and lobed, and sometimes running out into a slender point called an awn, sometimes with a bristle or awn on the back, &c. They also vary in size from the twentieth part of an inch to an inch or more in length.

Authorities consulted.—In the preparation of this work reference has been had to many authorities, both scientific and practical. Among those who have written practically on the uses and the cultivation of grasses the following-named works have been consulted and frequently qnoted. Flint on Grasses and Forage Plants; Grasses and their Culture, by Hon. J. Stanton Gould; Manual of Grasses at the South, by C. W. Howard; The Grasses of Tennessee, by J. R. Killebrew; The Farmer's Book of Grasses, by Prof. D. L. Phares, of Mississippi.

It is not thought necessary here to take up a systematic classification of the grasses farther than their arrangement in regular sequence, as the classification will be found fully described in the special report No. 63.

WINTER GRAZING IN THE ROCKY MOUNTAINS.

An article by General Benjamin Alvord, in a recent Bulletin of the American Geographical Society, with the above title, is deserving of extended publication and of careful study.

Our space will only allow us to give an abridgment of the article.

General Alvord says:

During the last fourteen years a revelation has dawned on the people of the United States, respecting the resources for winter grazing in the whole Rocky Mountain region. It is now known that all land over about 3,000 feet above the level of the sea has these qualities, viz, that without shelter, all the domestic animals can find ample food on the nutritious, summer-cured grasses of those plateaus, and that myriads of those animals are yearly raised by the great capitalists and others in our Western regions. The experiment has now for so many years been tried that it is not considered at all problematical, and although winters of great severity may occur, it is admitted that on an average the losses in the herds by the vicissitudes of the weather do not exceed 5 per cent. of the whole number.

General Alvord then proceeds to explain why this fact was so long unknown:

Surely it is extraordinary that so salient a fact as to the resources of this country should not have been fully known until the completion of the Union Pacific Railroad in 1869. My Army station from 1852 to 1865 was in Oregon or Washington Territory, and at Omaha from 1867 to 1871. Thus, I was thrown in the course of my official travels into regions giving me opportunities for observation, which I embraced. But I must confess that notwithstanding my knowledge of the benefits of the cured bunch-grasses in Oregon, east of the Cascade Mountains, and my large intercourse with emigrants yearly arriving on the Pacific slope, and with the officers and scientists of many exploring expeditions, it was not until during my residence in Omaha and my journeys over the Union Pacific Railroad that I knew of the immense resources for winter grazing on the Rocky Mountain plateaus which cover probably one-fourth of our whole territory. Our total area is 4,000,000 square miles, and we can safely add that the region for winter grazing is about a million of square miles, if not more—not including any portion of Alaska. The moment California, New Mexico, and the other

territories were acquired from Mexico in 1848, our Government turned its attention to the Pacific slope, and to the necessity of a Pacific railroad, and sundry exploring expeditions were organized in 1853 to examine the various routes—northern, southern, and central. These expeditions, and those preceding, of Lewis and Clarke, of Long, of Bonneville, and of Frémont, gave to the world a great mass of information of all kinds concerning those little known regions. Each of the Pacific railroad exploring parties had scientists of the greatest repute in various branches of investigation, as geology, botany, and natural history, and had with them experienced guides, hunters, woodsmen, mountaineers, and prairie-men; and all these were as ignorant as the rest of the winter resources of that vast domain. The reason was that all the explorations were made in summer, each party returning to winter in lower altitudes in the settlements without any attempt to discover and unveil the winter characteristics of the mountain regions.

We learned at Omaha that the discovery of the resources of the Rocky Mountain plateaus for winter grazing was really made during the war by the parties under that enterprising man, the late Edward Creighton (afterward president of the First National Bank of Omaha), who had taken the contract to build the telegraph line from Omaha to San Francisco. One winter their animals were left to graze in the elevated pastures of those regions, and were found in the spring in splendid order for the prosecution of their labors. This fact was utilized by Mr. Creigton, and it was the foundation of his large fortune, made in great part by stock-raising in Western Nebraska and Wyoming. These facts soon became known. By the time the Union Pacific Railroad was completed, in 1869, the enterprising capitalists and herdsmen of the West were aroused and ready to avail themselves of this new and promising mode of investment.

General Alvord proceeds further, as follows:

We will now undertake to explain the anomaly that the grasses of the arid plateaus are ready at all seasons for grazing, whereas in winter in all the lower altitudes they are not. Heat and moisture will cause the grasses in autumn and in winter to rot. With us they decay and, unless cut in season, cured and made into hay, are lost to use.

In the arid Rocky Mountain plateaus the grasses, as they stand on the soil, are cured in the sun during the summer, the action of heat retaining and concentrating in the stalks the sugar, gluten, and other constituents of which they are composed. This is true of the bunch grasses, the buffalo and grama, and many similar grasses which pervade those regions. It is so cold and so dry in those elevations that there are neither heat nor moisture to rot them. And the snows are so fine (save in some exceptional seasons) in that cold atmosphere, that they are so blown by the winds into drifts, that four-fifths of the soil is never covered by them. Thus, the grass is ever accessible to the domestic and other animals, while the snow is so fine that it falls from their backs; therefore they are not encumbered with a coating of frozen snow, which in the lower regions would go far toward killing the poor brutes. They find shelter in the hollows, bushes, and forests during very severe weather. In the natural abodes of the buffalo, antelope, and other wild animals, it is found that our valued domestic animals can in like manner survive the winter. Countless millions of buffaloes have ever subsisted on the buffalo grass. Although our domestic animals generally prefer the other grasses, the buffalo grass does not fail to be one of their resources.

The difficulties in lower altitudes than those I have described have been that after a warm spell and a thaw, the snow freezes to a crust and the grass is matted down by the ice, and kept from the stock. East of the Cascade Mountains, in the arid portion of Oregon, bunch grasses and cured grasses are found near the Dalles, where it is only 300 or 400 feet above the sea. In December, 1852, I witnessed such a thaw, followed by freezing, which kept the oxen from getting to the grasses, and consequently large numbers died of starvation. If they had been wintered near Fort Boise or any-

where 3,000 feet above the sea, they would have thriven on the rich bunch grasses ever accessible on those plains. Sheep should always have shelter from the cold winds, but no other stock requires it.

In Texas the grazing grounds are mostly at so low a level above the sea that the grasses rot in winter. Hence, in the latter part of winter, the animals there are often poor, and it is difficult to provide food for them. Thus it is that the vast herds started from Texas to be driven to market acquire flesh and improve every hundred miles of their journey north, as they reach new and well-advanced pastures.

But we must now allude to another element which prepares the elevated regions for winter grazing, viz, that the climate is much warmer than in the regions east of it in the same latitude. The isothermal lines all ascend in moving westward.

At Omaha cattle and horses must have shelter in winter, but none is needed at Fort Laramie. The extreme severity at Fort Buford, Dak., 1,900 feet above the sea is, in like manner, contrasted with the weather at Fort Phil Kearney or Powder River. 6,000 feet above the sea, or with the winter climate of Forts Custer and Keogh.

Scientists are not yet able to assign satisfactory reasons for these anomalies; perhaps they are inscrutable. Why in ascending the slopes of the Rocky Mountain plateaus a warmer climate should be encountered is a proper field for future consideration and investigation. It still remains a paradox.

We can make the following statement as to the region higher than 3,000 feet above the sea, fit for winter grazing. It includes all, nearly up to the timber line, of Montana, Idaho, Wyoming, Utah, Nevada, Colorado, and New Mexico, and five-sixths of Arizona, one-half of Dakota, one-third of Nebraska, one-fifth of Kansas, one-fourth of Texas, and one-sixth each of California, Oregon, and Washington Territory. This embraces, as we have already said, about one-fourth of the area of the whole United States.

Strange enough, all the best authorities who have had opportunities for comparison say that those regions farthest north are the best. Brisbin, page 90, says: "Montana has undoubtedly the best grazing grounds in America, and parts of Dakota stand next."

The writer thus engages in a consideration of the elevated plateaus of South America, Asia, and Africa, and a comparison with those of our own country, and thus proceeds as follows:

I shall now give some account of the various grasses which are found on the plateaus, and which are summer-cured. In Appendix C will be found a letter to me, of March 1, 1883, from Dr. George Vasey, botanist of the Department of Agriculture, who has complied with my request to give me a concise statement of the names of the principal grasses.

In general parlance it has been supposed that what are called "bunch" grasses are in the northern portions of the Rocky Mountain range, and that the "gama" or "grama" grasses were peculiar to the southern territories in New Mexico and Arizona. But I am satisfied, from personal inquiries of travelers (Marcy and Dutton among others), as well as from the statements of the botanists, that both the "bunch" grasses and others are found in each region. But it seems probable that the "gama" and "grama" grasses are found in the greatest abundance in the more southern portions. The "buffalo" grass or grasses (for the term is applied to more than one kind) are found throughout all the ranges of the buffalo from north to south. The term "bunch" grass was given because it grows in tufts or bunches a foot or more in height, sometimes two feet apart, so that the aspect from surrounding hills would often be that of a desert region. A green carpet is never or rarely seen. The buffalo grass grows as a low tuft, and it is summer-cured as it grows, like the other grasses under consideration.

By the courtesy of General F. A. Walker, Superintendent of the Census, I had the privilege of reading (before publication) a full and interesting paper by Prof. William

H. Brewer on "Pasture and Forage Plants." In the following statement I have often availed myself of some items from it.

The term "bunch grass" has been applied to several kinds, and we will name those prominently known:

The *Festuca scabrella* is the one best known on the Pacific slope, ranging from California to Oregon and Idaho.

The *Festuca occidentalis* is also found there.

The *Festuca ovina* (or sheep grass) in several varieties is found through the whole region of winter grazing, and seems the world over to be found wherever sheep graze.

Eriocoma cuspidata is one of the valuable bunch grasses generally prevalent.

Of the grasses termed "grama" *Eragrostis poœoides* and *Eragrostis oxylepis* are called grama grasses. The former in Texas is sometimes called one of the buffalo grasses.

Munroa squarrosa, Mr. Brewer says, is a buffalo grass of the north, and one of the grama grasses of Texas. *Calamagrostis longifolia* has a wide range and is sometimes called "mesquit" and grama grass, and *Calamagrostis canadensis*, sometimes called "blue joint."

The terms "gama" and "grama" are not interchangeable. Mr. Brewer says that *Tripsacum dactyloides* is the "gama grass" of the South—a tall, coarse grass, from 3 to 7 feet high—and is found from Texas to Illinois and Connecticut.

Though much confusion of names is in popular use in reference to all the grasses it seems to be admitted that the term "buffalo grass" is applied most justly to *Buchloe dactyloides*. It is one of the most nutritious of grasses and pervades the whole range of the Rocky Mountain plateaus.

The following is the letter of Dr. Vasey, referred to in the preceding paper:

DEAR SIR: In reply to your request I offer the following remarks on the native grasses of the great plains and arid portions of the West. These grasses furnish the chief resource of the immense herds of buffaloes and the vast droves of domestic animals which feed upon the plains, and from the habit of growth are, for the most part, known by the name of bunch grasses. They are chiefly grasses of rigid aspect, at least as respects their culms and leaves, some of them, however, forming a diffuse and elegant panicle of flowers. The most important of the bunch grasses may be briefly mentioned as follows:

Of the genus *Stipa* there are several species. *Stipa comata* and *Stipa setigera* occur abundantly in New Mexico, Texas, Arizona, and the drier regions of California, reaching to Oregon. In Colorado, Kansas, and all the prairie region northward, stretching into British America, the *Stipa juncea* is the principal one of the genus. On the higher plateaus and near the mountains the *Stipa viridula* is very common, extending from Arizona to Oregon and British America. Somewhat related botanically is *Eriocoma cuspidata*, a very rigid bunch grass with a fine, handsome panicle of flowers. It is equally widespread with the preceding. Another widely-diffused grass is *Aira caespitosa*, varying much in size and thriftiness according to the altitude and amount of moisture where it grows, but always having a light, elegant, spreading panicle of silvery-gray flowers.

One of the most extensively-diffused grasses is *Koeleria cristata*, varying in height from one foot to two and a half feet, with a narrow and closely-flowered spike. Several species of fescue grass (*Festuca*) are intermixed with the vegetation in varying proportions; the most important of these are probably the *Festuca ovina*, in several varieties, and *Festuca scabrella*, the latter especially in California, Oregon, and Washington.

The genus *Calamagrostis* furnishes several species, which contribute largely to the vegetation of this region. They are mostly tall, stiff, and coarse grasses, but leafy, and some of them very nutritious. Of these *Calamagrostis sylvatica* and *C. stricta* are

least valuable. Perhaps the best of them is *Calamagrostis canadensis*, which is soft and leafy. Next, perhaps, in value is *Calamagrostis aleutica*, of California and Oregon, extending into Alaska. *Calamagrostis longifolia*, confined chiefly to the plains east of the Rocky Mountains, is tall and reed-like, growing in dense clumps, from four to six feet high. Several species of *Andropogon* are diffused from Arizona to British America on the plains, but are not found on the western coast. They are, however, not properly called bunch grass, as their habit of growth is more spreading. The principal species are *Andropogon scoparius*, *A. furcatus*, and *A. nutans*. Some of them are known through the plain region as blue-joint or blue-stem. Others, more sparingly spread, are several species of *Poa* and *Glyceria*. Several varieties of *Triticum repens* or couch grass occur abundantly in saline soils, and are among the most nutritious of grasses. *Brizopyrum spicatum* and species of *Vilfa* and *Sporobolus* also form extensive patches or meadows in saline soil. Besides the grasses already mentioned there are a large number of low growth and more diffused habit, which are known in the Southwest and east of the Rocky Mountains under the names of mesquit and buffalo grasses. The former belong mostly to the genus *Bouteloua*, the most important species being *B. curtipendula*, or tall mesquit, and *B. oligostachya* and *B. hirsuta*, or low mesquit. The true buffalo grass is botanically *Buchloe dactyloides*, which in some places forms extensive fields of its low and densely-tufted growth. Another similar grass spreading out in low patches is *Munroa squarrosa*. The above-mentioned species form the larger proportion of the grassy vegetation of the great plains.

Respectfully,

GEO. VASEY,
Botanist.

General BENJAMIN ALVORD.

REPORTS ON GRASS AND GRASS CULTURE FROM ALL PARTS OF THE UNITED STATES.

In 1882 circulars were sent out by the Commissioner of Agriculture to agriculturists and farmers in all parts of the country asking information as to the natural pasture grasses of this district, what kind of natural and cultivated grasses were used for hay and pasture, and what grasses could be suggested for experiment. A large number of reports were received and compiled by the assistant botanist, W. P. Conant, and a summary of the results is herewith given. As a general thing the correspondents were not acquainted with the botanic or technical names of the grasses, and gave the common or local name where there was one. It frequently happens that the same grass will have different local names even in places not far remote from each other, and also that the same name will be applied to grasses very unlike. Many have no common name and are referred to as wild grass, woods grass, swamp grass, &c.

So, in examining the reports, a perplexing difficulty was often encountered in not being able to determine to what species a grass belonged from the name given. In some instances this difficulty was obviated by obtaining specimens of the plants referred to; in others they were not sent or failed to reach here.

The reports were sent in with commendable promptness, and all evinced a great interest in the subject, and expressed a strong desire to aid the undertaking by all means in their power.

WASHINGTON TERRITORY AND OREGON.

From Washington Territory twelve reports were received, and from Oregon thirty-one. They are so much alike that we consider them together.

NATIVE PASTURE GRASSES.

Bunch-grass is found in the drier places and on the hills; wild pea-vine and a few wild grasses in the timber; clover upon bottom-lands; wild rye-grass, a species of *elymus*, upon lowlands, and a variety of mixed grasses upon the prairies.

Several species of grass are called bunch-grass, the principal of which are *Poa tenuifolia* Nutt, *Festuca scabrella*, *Eriocoma cuspidata*, and some of the species of *Stipa*.

Bunch-grass, which formerly was the principal pasture grass upon the uplands, has become about extinct, partly from the land being taken for cultivation and partly from overfeeding. Its place has been taken by wild chess (*Bromus secalinus*) and other poor grasses.

But little native grass is cut for hay; some little wild red-top, wild-rye grass, salt-marsh grass upon tide-water, and, east of the Cascades, a little bunch-grass is cut.

CULTIVATED GRASSES.

Timothy is found universally distributed throughout this section, and has become so well established that some consider it indigenous. It has so tenacious a hold upon the soil that it can scarcely be killed out. As a hay grass, timothy has no superior; for a pasture grass, it gives out too early in July.

Next in general diffusion come the clovers and orchard grass. Red-top, also, is quite common. Kentucky blue-grass, though not so extensively introduced, seems well adapted to some portions of this section.

The soil and climate of Oregon and Washington Territory are admirably adapted to the culture of grass, and any kind will do well if allowed a fair chance. There is a great diversity of soil; and often on the same farm all kinds may be found, from the black sandy loam to red clay.

From some, come inquiries for a grass that will do well upon lands worn out by constant wheat-cropping; others say that they are sowing clover on their exhausted lands to recuperate them, and no better advice can be given the former than to do likewise. By this means the tired lands can soon be restored to fertility.

A better way, and one which the intelligent farmers will soon learn to follow, is to avoid depleting the land at all, but by a suitable rotation of crops, among which the clovers and grasses should have a prominent place, the lands can be kept in a normal state of fertility, and, being naturally rich, will yield a generous reward to the husbandman's toil.

CALIFORNIA.

From California thirty-seven reports were received. They give th following as the principal grasses:

NATIVE PASTURE GRASSES.

Wild oats (*Avena fatua*), alfilaria (*Erodium cicutarium*), bur-clov (*Medicago denticulata*), wild clovers, of which there are several speci and bunch-grass, in the order named. In the northern part of the Sta a little wild rye-grass (*Elymus*), wild red-top, and wild pea-vine a found.

Accounts from the central and southern counties state that the nati bunch-grass, which formerly furnished a nutritious feed for a large p of the Pacific slope, has of late years become about extinct, and in so sections the alfilaria, bur-clover, and other forage plants, which w found on the uncultivated lands during spring and early summer, a slowly but surely dying out, and their places are being taken by worthless grass that nothing will eat green or dry.

Mr. C. O. Tucker, of Ballena, attributes this gradual disappearan of the native grasses to the constant and too close pasturage at a prior to the time for maturing their seeds, and to a too persistent p turage with sheep at other times, causing the ground to become th oughly trodden and compacted. This has been followed during t last few years by unusually hot and dry summers. He knows of section where the need of useful forage plants is more severely felt th here.

Mr. Mart. Walker, of Saint Helena, says that there is an intense d sire among farmers to obtain a grass capable of resisting the inte heat and drought of summer, and afford grazing for cattle during th period, and if possible one that will grow on poor soil. For the w of some such resource many districts are fast becoming worthless. says that this results from the system of continuous cropping to wh the land has been subjected for the last thirty years.

NATIVE GRASSES CUT FOR HAY.

Except wild oats and bur-clover but little native grass is cut for ha In the northern part of the State a little wild-rye grass, wild red to and in some localities rushes are cut.

CULTIVATED GRASSES.

The various grains, as wheat, rye, and barley, cut when in the mi are principally relied upon for hay in many parts of California. Th come as volunteers, or very often after the grain is taken off a "h cast" of seed is sown on the stubble at the first rain in the fall a harrowed in. Wild oats are cut extensively, and alfalfa (*Medic sativa*), often called lucern, is cultivated largely for hay, especially

ıe southern part of the State, where by irrigation large crops are ıade.

In the northern and central counties timothy and clover are cut to ɔme extent, and are commented on favorably. Thus far but very lit- e attention has been given to this subject. The general system of ırming in vogue here is so different from that of other parts of the ɔuntry, and so few experiments have been made, that no particular rasses or forage plants can be recommended at this time.

Further experiments and developments will have to determine the ɒportant question.

IDAHO AND MONTANA.

Bunch grass is common throughout the hill country. In the lowlands ıe wild rye grass and other coarse grasses are found. Timothy is ınd successfully cultivated everywhere. In Idaho clover is culti- ıted extensively, especially in the Boise Valley, where some very large ɔps are reported. Some farmers have put their whole places in it. he small red clover is preferred. Alfalfa succeeds well in Montana.

Timothy and clover are recommended for the bottoms, and alfalfa for ıe "bench lands." All the grasses would succeed well with attention. he soil and climate are well adapted to their growth, and all things eem favorable to their culture, both for pasture and hay. All the ırmers have to do here is to avoid the mistake made in many new sec- ɔns, that of overpasturing and continuous cropping, and for years ɔ come they will have a never-ceasing source of wealth.

UTAH.

The principal native pasture grasses of Utah are the bunch grass, wire rass (*Juncus Balticus*), salt grass) *Vilfa depanperata*), and buffalo grass *Buchloe dactyloides*). The wire grass and salt grass are cut for hay. Lu- rn, or alfalfa (*Medicago sativa*), is cultivated for forage and hay to a reater extent than anything else, and succeeds well. In some counties arcely any other forage plant is cultivated.

Clover is reported successful in some places and timothy in others, hough neither has been cultivated largely.

NEW MEXICO.

The gramma grass (*Bouteloua*) is common on the high ground through- ut New Mexico. On the river bottoms there is a little blue grass. Al- lfa has been cultivated more than any other forage plant, and on the bot- ɔms will thrive after the second year without irrigation. The millets ıve been raised some, and should receive more attention. No experi- ents worthy of note are reported.

The reports from Utah and New Mexico were so few in number, and ıe area so great and so diversified that no suggestions can be made as ɔ what grasses will be best adapted to this section. Many experi- ents will have to be made to determine this.

TEXAS.

NATIVE GRASSES.

From Texas there were sixty-nine reports. The natural pasture grasses consist of the mixed grasses usually found on the prairies which occupy so large a part of the State. The sage or sedge grass holds a prominent place among them; but when overpastured it is run out, and the mesquite, both hardier and better, takes it place. The mesquite is found in the northern, central, and southern parts of the State, but not much in the northeastern part.

The term mesquite is used somewhat indefinitely, being applied to a number of grasses, but here it is probable that the buffalo grass of the plains (*Buchloe dactyloides*) is meant. It is found chiefly on the black lands. The gramma grass (*Bouteloua*), of which there are some patches, is rapidly disappearing, and is being replaced by the mesquite. Prairie grass thus far has been the chief reliance for hay as well as pasture.

Texas has always been a great stock-raising State, and while the range was uninterrupted no attention was given to cultivating grass or to improving pastures. But of late years portions of the State have been rapidly filling up, and the range consequently diminishing, so now the farmers are giving considerable attention to improving their pastures and to the hay crop. This, intelligent farmers write, should receive all the encouragement and assistance possible.

Mr. Talley says that the greatest difficulty in making the culture of Kentucky blue grass a success is in getting it to live the first year. The same remark is applicable to most of the grasses. The main reason of failure, he says, is not so much on account of the drought as on account of the nature of the soil. It is loose and porous and dries up very quickly on the surface; hence they often find it difficult to get a "stand" of turnips in the fall or a "stand" of millet in the spring. The soil holds moisture well below the depth of 2 inches.

He further says:

> I have taken great interest in investigating the subject of grasses, and my labor were awarded by finding a much greater variety on my place than I had ever suspected, and all I have to do is to cultivate and take care of what I already possess and cut the weeds to prevent their shading and smothering out the grasses already in the ground.

Texas is naturally a great State, and only needs fair attention to succeed. Johnson grass and Bermuda are receiving considerable attention, and for the most part are spoken of favorably.

Bur, or California clover, does well in this State, and is highly esteemed in California for the feed it affords, though the burs or seed pods stick to the wool of sheep and impair its value. Alfalfa is cultivated largely here, and does very well. Timothy, orchard grass, and clover are not reported on so favorably as could be wished.

The millets are cultivated quite extensively and do well. Mr. Clark

of Hempstead, Waller County, Texas, has recently sent to the Department samples of several kinds, among which were specimens of the so-called double-headed German millet 4½ feet high, and estimated to yield 3 tons to the acre.

Mr. W. H. D. Carrington, of Austin, says that there is but one native grass cultivated for hay, and that is what is called Colorado bottom grass; sometimes called goose grass, and in some places Green River grass (*Panicum Texanum*). The method of culture most commonly adopted is the same as that for crab grass. It comes voluntarily after corn is "laid by." A few farmers have found it so profitable that they plow and harrow their land in winter and cut the grass as soon as it matures. In this way they secure two crops annually. It is preferred by all kinds of stock to Hungarian grass or to oats in the sheaf. It seeds itself freely. The hay sells now (February, 1882), at $25 per ton, while prairie hay sells at from $10 to $12 per ton. This might be introduced into the other Southern States without requiring any change in the method of culture generally pursued. It is figured and described in the report for 1879.

THE SOUTHERN STATES.

The returns from Georgia, Florida, Alabama, Mississippi, and Louisiana are so similar in general character that they are considered together, differences being noted as they occur.

NATIVE PASTURE GRASSES.

By an examination of the returns from this section, crab grass (*Panicum sanguinale*) is found to be the most extensively diffused pasture grass for summer and fall grazing, while crow-foot (*Eleusine Indica*) is quite common in Georgia and Florida.

The sedge grass also holds a prominent place as a pasture grass in Georgia, Alabama, and Louisiana, being reported from nearly one-half the counties. Several grasses are called sedge and broom sedge. They are for the most part some species of *Andropogon* or *Stipa*.

Bermuda grass (*Cynodon dactylon*) is reported in over one-third of the counties, and is probably growing in many more, and though an introduced grass it has become so well established that it is generally referred to as a native. The wild pea vine is also plentiful and in some places quite popular. In Florida it is said to do well on the poor sandy soil, and to endure the heat and drought of summer. Mexican clover (*Richardsonia scabra*) is spreading over the sandy uplands along the coast. Tick trifoil, or tickseed, two species of *Desmodium*, is frequent in rich woods, and is esteemed as a milk-producing plant. Nimblewill (*Muhlenbergia Mexicana* and *diffusa*) are found in open woods in the northern and central counties.

In Alabama and Mississippi, Japan clover (Lespedeza striata) has spread extensively over the roadsides and uncultivated fields. It will

grow upon all soils, even the poorest, and withstands the heat and drought of summer remarkably well. It spreads rapidly, and some say it will root out the broom sedge and even Bermuda. It is rather a coarse plant, and should be tried only in places unsuitable for the better grasses. In Louisiana, crab grass, though still common, is gradually giving place as a pasture grass to Bermuda and white clover. Several species of clover seem to be spreading over this section; some of them are said to afford considerable seed.

The bur, or California clover (*Medicago denticulata*), is reported in two counties of Alabama, and has been successfully tried in Georgia. In California it is highly esteemed.

Paspalum ovatum is found in Texas and Louisiana. It is highly spoken of as a pasture grass by those who have examined it. (See report of the botanist for 1880.)

Numerous other grasses are found growing with the foregoing species, but generally are of no particular value, and having for the most part no common names, they are spoken of as wild grasses, &c.

In regard to native pasture grasses, Mr. Hawkins, of Hawkinsville, Ala., says:

> There is but very little grass of any kind here, except the wild varieties which come spontaneously on all old fields with the broom sedge, and our very best pastures are on these old fields. Old fields when turned out usually grow weeds the first two years, and require about four years for them to become sodded with broom sedge. Burn this off in early spring, and with sufficient cattle it need never be burned again, as the cattle will keep it down. I have an excellent pasture of 150 acres of this kind, which will keep in good condition thirty head of cattle, half as many mules when not at work, and some hogs.

NATIVE HAY GRASSES.

In this section crab grass is cut very extensively, being reported from nearly every county where any attention at all is given to hay. Crow-foot, as a crop grass, is chiefly confined to Georgia. Some of the coarse swamp grasses are cut to a considerable extent in certain localities.

CULTIVATED GRASSES.

Over one-half of the reports from this section state that no attempts have been made to cultivate grass for hay. They rely entirely upon the volunteer grasses, the principal one being crab, which some consider to be superior to the so-called cultivated grasses.

The chief reasons given in favor of crab grass as a pasture grass and for hay are that it is indigenous, and therefore well adapted to withstand the effects of the climate; that the ground has only to be smoothed after the corn is "laid by," and it comes voluntarily; that it never fails, and does well on poor and sandy soil.

In the remaining counties more or less introduced grasses have been

cut for hay, consisting principally of herds grass (red top), the clovers, timothy, and orchard grass in the order named. Bermuda grass is reported to be cut for hay to a greater extent than any other, except the crab grass. The millets are cultivated for hay, and are deserving of more attention, for, being annuals, they can be grown successfully in all parts of the South. In Louisiana the cow-pea is considered one of the best forage crops, and its cultivation is extending. In the Red River district sorghum of various kinds is largely raised for food.

JOHNSON GRASS.

Johnson grass is steadily growing in favor and its cultivation extending. It is being introduced on the low, wet prairie lands of Texas, and the reports are quite favorable. It is essentially a hay grass, and may be cut three or four times a year. It should always be cut before the seed stalks run up, else it will be too coarse. It is even more difficult to exterminate when once well set than Bermuda, hence should not be allowed to seed. The best way to eradicate it is by frequent plowings in July and August, exposing the roots as much as possible to the sun. It will not bear tramping.

Both this grass and Bermuda are regarded as a great blessing, or as an unmitigated evil, according to the standpoint from which they are viewed. The exclusive cotton-planter is apt to look upon them with unabated hostility, while those who are beginning to diversify their crops look upon these and other grasses as a great boon.

In these States hay should be secured early enough in the season to allow the meadows to get a good start before the summer drought sets in, so that the roots may have a good protection during this trying period. Meadows should not be pastured until the fall rains set in, and then only lightly, and never when the ground is soft from much rain. Care should be taken not to pasture too late in the spring, thereby preventing the grass from growing tall enough to cut before the heat of summer. According to the reports, the farmers are accustomed very generally to pasture too closely, which causes great injury, if not destruction, to the grass.

PERMANENT PASTURE.

For a permanent pasture grass the Texas blue grass (*Poa arachnifera*) promises to be one of the very best grasses yet brought to the attention of the South. It is a strong, deep-rooted grass, with an abundance of foliage, and seems to possess all of the characteristics necessary for a grass to be successful in most parts of the South. It grows in woods or open prairie, and thrives upon a variety of soils, poor as well as rich, but has not, so far as reported, been tried upon a dry, sandy soil. This grass seems worthy of earnest consideration by

all interested. As it is figured and so fully described in another part of the report more need not be said here.

The Texas blue grass dies down during the heat of summer and springs up with the first fall rains and lasts till summer again. Bermuda comes in early spring and lasts till frost comes, thus being a summer pasture grass.

WINTER PASTURE.

From several places, especially in Georgia and Alabama, requests come for a grass that will make good winter pasture, and if possible one that will succeed upon weak, sandy soil. The cultivated grasses best adapted for winter pasture at the South are the tall meadow oat grass (*Arrhenatherum avenaceum*), which will thrive on more sandy soil than most of the cultivated grasses (though it prefers a rich upland), and will yield more green food in winter than any other grass.

Orchard grass (*Dactylis glomerata*) is next in value. It does well in orchards and thinned woods, and will do well on any rich, dry soil. After being cut or eaten down by stock it springs up again with great rapidity, thus rendering it of peculiar value as a pasture grass. Experiment demonstrates that these grasses will thrive and do well in the northern and central counties of the Gulf States, and ought to succeed in all sections, except, perhaps, on a very dry, sandy soil. These two grasses are thought to endure the heat and drought better than other cultivated grasses. Italian rye grass (*Lolium Italicum*) is one of the very best grasses for this section. By being sown and harrowed in at the first fall rains it will be ready for pasture by midwinter, and will afford a rich pasturage during the latter part of winter and spring, and can then be plowed under for the following crop, thus enriching the land as well as furnishing abundant winter feed. By only pasturing very lightly a crop of hay can be cut and the stubble turned under for a following wheat or other grain crop. The attention cannot be too strongly called to this useful grass. Wild rye grass (*Elymus*) and wild meadow barley (*Hordeum pratense*), also the common cultivated rye and barley, make excellent pasture.

BERMUDA GRASS.

Bermuda grass has of late attracted more than usual attention. It has been referred to and discussed by so many of the correspondents that an idea of the estimation in which it is held cannot be better given than by making a few extracts from their letters.

Mr. Hawkins, of Barbour County, Alabama, says that he is very certain now, and has been for years, that the great want of the South is a grass with which the tired lands may be seeded, and some return had while the land is being recuperated. Bermuda, he says, is the grass to do this if it seeded, and could be easily destroyed when the land is wanted for cultivation. These difficulties, he says, operate suf-

ficiently to almost exclude it from the tillable land. A correspondent from Mississippi says:

Bermuda is the grass for this country, resisting both the drought of summer and the frost of winter, and affording a richer pasturage than any other grass. With this for pasture and the Johnson grass (*Sorghum halapense*) for hay, stock-raising will be more profitable than cotton.

Georgia has taken the lead in introducing Bermuda grass. In the central part of the State it is found in every county, and is steadily growing in favor. The report of the State board of agriculture for 1881 says:

The hay crop of Georgia has been unusually fine in 1881. The clovers and cultivated grasses made heavy crops before the summer's drought commenced. Large harvests of Bermuda hay were realized in some of the counties of Middle Georgia, where this valuable grass is being more highly appreciated every year. It makes a hay inferior to none, with the advantage of being permanent when once well set. Quite a number of farmers now realize a better income from lands set in Bermuda than they did from the same when in cotton.

Another correspondent says:

Bermuda, beyond all doubt, is the best grass for pasture, but for hay we need other grasses, and I am satisfied that Johnson grass is the one for that purpose. These two grasses have the power to make this section a great stock country.

Such expressions as this frequently occur in the reports: "Bermuda is the best, but the farmers are afraid of it."

Mr. F. Seip, of Rapides Parish, Louisiana, says:

Of all the usual cultivated grasses none can compare in general usefulness to the Bermuda. It is invaluable as a pasture grass for all kinds of stock, furnishing, through nearly the entire year, and even in winter, under some circumstances, an extraordinary amount of food. For hay purposes it cannot be surpassed. Under favorable circumstances it will yield more to the acre than any other known grass, with the exception possibly of lucern (*Medicago sativa*) and Johnson grass, the latter being too coarse to make superior hay.

Again Mr. Seip says of Bermuda:

It can only be recommended for permanent pastures or meadows, as it is very difficult to eradicate, but still it is practicable to remove it. The best method, I think, is summer plowing repeated frequently, followed by oats in the fall and winter, and after the oat crop by a heavy crop of pease. If this is well done there will be no trouble in making a crop of corn or cotton the following year.

Colonel Lane, in "Forage Plants of the South," says, in reference to destroying Bermuda:

Upon ordinary upland I have found no difficulty in destroying it by close cultivation in cotton for two years. It requires a few extra plowings to get the sod thoroughly broken to pieces. The breaking should be done with a small plow first and a harrow run over it once or twice in winter or early spring. Take advantage of the dry hot months of summer to have the grass that may be found alive plowed and hoed, and exposed as much as possible to the sun. In ordinary seasons so much of the grass will be killed the first year that but little interference with the next crop need be apprehended.

Bermuda is essentially a Southern summer-pasture grass, and as such possesses superior qualities. It will thrive upon poor soil and stand the heat and drought of summer. It is nutritious, and is eaten by all kinds of stock. It is permanent when once well set, provided it is pastured; otherwise, the broom sedge and other grasses will run it out. It requires tramping to flourish. The objections it encountered during the first years of its introduction have gradually given way, as the farmers have seen more of it and have become better acquainted with its nature and habits. To make hay it requires a rich soil—a soil rich enough to produce good crops of timothy and the more valuable grasses. It is an ameliorating crop. A field kept in Bermuda a few years will become so enriched that should it be wanted for cultivation the increased crops will more than pay for the extra labor and expense required the first year on account of the sod.

Often in the reports a request is made for a grass that will do well on their exhausted lands and yield some return while they are being recuperated. Lands naturally fertile, but depleted by cropping, if not "turned out in commons," can be recuperated by proper management through the agency of ameliorating crops, the particular ones to be used varying with the different conditions of location, nature of soil, &c., and cannot be entered into minutely here, but which the intelligent cultivator will soon learn to determine.

Immediate and constant returns, as some ask for, should not be expected from a soil already exhausted. But in a short time, by generous treatment, they can be brought to a condition to once more reward the toiler for his labor, and will prove in the end to be much more economical than to "turn the fields out" and wait thirty or forty years for the slow process of natural recuperation, expending meantime ones energies in clearing and bringing into cultivation new tracts, to be in turn abandoned and "turned out."

Some ask for a grass that will do well upon a soil naturally poor or barren. Such a soil will not yield anything without fertilizing except a few worthless weeds or some of the coarser plants. Good grasses will not grow on land that will not produce medium crops of grain. By using fertilizers and turning under green crops the productiveness can be increased so as to give fair returns, and then by suitable rotation the land can be continuously improved.

EXPERIMENTS.

In nearly one-half of the counties, according to the reports, no experiments introducing new grasses have been made, while in many of the other counties they have been made only on a small scale, and were too often abandoned as failures before they had been fully tested. Failures frequently result from not fully understanding the nature and re-

quirements of the grasses, especially during the early stages of their growth.

Mr. J. J. Barclay, of Wheeler, Ala., says:

I have experimented on my place with most of the cultivated grasses, and find they do well if protected from the tramping and depredations of stock for one season. * * * I am confident of their success and feel that their introduction into this portion of the South will be of incalculable benefit to the country and people, and especially attractive to the immigrant, whose first question is, "Do grasses grow in your State?"

Another says that orchard grass, tall meadow oat grass, and Johnson grass will do well if properly attended to and the ground suitably prepared. Mr. Hawkins says that his experiments show that any of the grasses will do well upon rich loam, or on moist, stiff land, or on moist, sandy land. Mr. D. P. Hurley, of Pike County says:

I would add, on the important subject of grasses, that their cultivation is sadly neglected, not because the climate is hostile or the soil unadapted, nor because they cannot be successfully cultivated, but for the reason that diversified agriculture is practically disfavored.

Mr. P. M. Morehouse sent from Texas a sample of Kentucky blue grass, grown on the open prairie, without shade or extra care after well set. It has withstood the heat and drought of summer for three years extremely well. Yet there are large tracts of country, often embracing counties, where a meadow of grass is not to be found. Mr. Hawkins says that he does not know of a meadow of cultivated grass in Southeastern Alabama. Similar statements come from Louisiana. This unfavorable condition has arisen from several influences which can only be referred to here. Among them may be mentioned the custom of exclusive cotton planting which has been so sedulously followed for so many years, leaving but little time for anything else; also the habit of "turning out" fields when depleted instead of recuperating them by ameliorating crops.

Another is the reluctance and hesitation which persons naturally feel about changing old-established ways for untried methods, without the encouragement and aid of example to guide them in their new enterprise. The want of seed has been quite an impediment to increased attention being given to the grass crops. The correspondents say that a liberal distribution of grass seed would relieve a deeply-felt need and do much toward determining the important question of extending grass culture.

Fifth inquiry. "Please suggest any grasses that might be useful in your section."

The replies to this request were somewhat limited, and often rather suggestive than definite. There are but few to be added to those already mentioned. But for convenience, all of the grasses recommended for trial will be given here, together with such suggestions as the gen-

eral tenor of the reports and correspondence, and information obtained elsewhere, would seem to warrant. They recommend as follows:

For Washington Territory and Oregon.—Italian rye grass, tall meadow oat grass, Kentucky blue grass, Texas mesquite, and Bermuda.

For California.—Timothy, large red clover, the millets, orchard grass, Italian rye grass, white clover, Guinea grass (*Panicum jumentorum*) Bermuda, alfalfa, and Johnson grass.

For Idaho and Montana.—All the grasses for bottom lands, and alfalfa for "bench lands."

For Texas.—Alfalfa, Bermuda, timothy, the clovers, orchard grass, Johnson grass, and the millets in the order named.

For Georgia.—Kentucky blue grass, orchard grass, herds grass (called red top in New England), timothy, the clovers, and alfalfa, in the order named.

For Florida.—Bermuda, alfalfa, Guinea grass (*Panicum jumentorum*), orchard grass, Johnson grass, and clover.

For Alabama.—Orchard grass, Kentucky blue grass, timothy, herds grass (red top), Johnson grass, alfalfa, and California clover.

For Mississippi.—Orchard grass, herds grass (red top), the clovers, Kentucky blue grass, and the millets.

For Louisiana.—Kentucky blue grass, orchard grass, Bermuda, timothy, herds grass (red top), the clovers, and alfalfa.

The above are the principal forage plants enumerated for trial. It will be observed that in some instances instead of suggesting new grasses for trial those are named which have already been so fully tried that there is no question about their success.

It appears from the reports and correspondence that the principal need of Washington Territory and Oregon is a pasture grass for the dry hills in place of the nearly extinct bunch grass; some are desirous that Bermuda and Texas mesquite be tried. The latter has already been reported as successful in several counties. There is some uncertainty concerning what grass is referred to, as several go under the name of mesquite. It is probable that some mean the *Buchloe dactyloides*, the buffalo grass of the plains, a valuable pasture grass and similar in habit to Bermuda. In Texas it is called mesquite. The suggestion of these correspondents appear worthy of attention.

In Southern California some wish Bermuda to be tried for their pasture land which cannot be plowed, and where the bur-clover, &c., is being tramped out. They also think that the Guinea grass (*Panicum jumentorum*) might possibly succeed.

The suggestions from Florida were from only a few counties; the general impression seems to be that crab grass and other native grasses are superior to the so-called cultivated ones. Some think that a grass will have to be obtained from Cuba or the tropics to be suited to the climatic conditions existing there.

DESCRIPTION OF GRASSES.

PASPALUM, Linn.

Flowers in narrow, mostly linear, spikes, of which there may be one, or several crowded at the summit of the stem, or they may be more or less numerous, and arranged along the general peduncle. The spikelets are mostly obtuse and arranged in one or two rows on each side of the generally elevated crest or midrib of the flattened rhachis. The spikelets contain each one perfect flower inclosed within two outer membranaceous glumes; rarely one of the outer glumes much reduced or wanting. The glume of the perfect flower, called the flowering glume, is more or less convex or rounded on the back, usually thick and indurated, and incloses the shorter palet, which is of similar texture with the three stamens and two distinct plumose styles.

This genus has its range principally in the Southern States. They are mostly perennials, varying much in form and habit. Some are tall and erect, some decumbent or spreading, and others have the habit of sending out prostrate runners which take root at short intervals and thus spread and form dense patches. Several species may often be found in the same field. Professor Phares, of the Agricultural and Mechanical College of Mississippi, says:

> They are all succulent, tender, nutritious, hardy, thrifty, and relished by all grass-eating animals. They fill the soil with a matting of roots and cover the surface densely with luxuriant foliage from early spring till autumnal frosts.

PASPALUM LAEVE. (Smooth paspalum.)

This species grows from 2 to 4 feet high. The stem and leaves are smooth or smoothish, the lower leaves long and firm, the upper ones shorter and distant. Near the top of the culm are three to five slender spreading spikes, each from 2 to 3 inches long and 1 to 2 inches distant. There are a few longish hairs at the base of the spikes where they separate from the stem. The spikelets, or what becomes the seed, are oval, smooth, about one-tenth of an inch long, close together in two rows, which are wider than the narrow, slightly wavy rhachis.

Professor Phares (above quoted) says he has a neighbor who has been feeding this grass for twenty-five years; and for many years has had a meadow of it from which without ever having seeded, he annually mows about 2 tons of hay per acre. It should be cut before the seeds get ripe enough to fall off. (Plate 1.)

PASPALUM DILITATUM. (Hairy-flowered paspalum.)

This species is quite similar to the preceding, but taller and stouter. The culms are from a thick perennial rootstock, erect, 3 to 5 feet high, smooth, and with three to five leaves from as many smooth, purplish joints. The leaves at the base of the culm are numerous, about a foot

long and one-third to one-half an inch wide. They are smooth on both sides and roughish on the margins. The raceme is from 5 to 8 inches long, composed of from five to ten somewhat spreading spikes, which are 3 inches or more in length, and 1 or 2 inches apart on the rather slender axis, the upper ones are gradually shorter, all with a few long hairs at the base. The spikelets are closely arranged in four rows, two on each side of the narrow and nearly straight axis, in alternate pairs. They are about one and a half lines long, ovate, acutely pointed, crowded and overlapping each other, compressed, and the margins clothed with silky hairs. The two outer or empty glumes are ovate, acute, five-nerved, nearly smooth, except the fringe of thin white hairs on the margin. The flowering glume is thick and firm, and very delicately punctate under a magnifier. The palet fits inside the margin of the flowering glume and inclosing the stamens and styles. This species has been found in Virginia, Alabama, Mississippi, Louisiana, and Texas. It is also a South American species. It has been called *Paspalum ovatum*, but the name first given is the proper one. It was described in the Agricultural Report for 1880, and has since then been noticed and experimented with by several persons. (Plate 2.)

Several other species of the same general appearance and habit occur in the Southern States, among which may be named *Paspalum lentiferum*, *P. Floridanum*, and *P. plicatulum*. Quite recently another species has been brought to our notice by Mr. H. B. Richards, of La Grange, Tex. It has been called *Paspalum remotum*, and Mr. Richards states that it roots at every joint and sends up shoots like a layered grape vine; it remains green all winter, and it is almost impossible to destroy it by cultivation. Plowing spreads it, as every stem broken off takes root again. It can only be killed by digging out every particle and exposing it to the hot sun. All soils seem to be equally acceptable to it; it grows as well in the shade as in the sunshine. Drought does not seem to affect it. Stock like it both in winter and summer. A single seed or joint has been known to spread over an area of five or six feet in diameter in a single season, with a perfect mat of grass firmly rooted all over. It evidently will bear close pasturage and hard tramping. The difficulty of eradicating it will be an objection to it in the opinion of some, but where it is desirable to make a permanent pasture this feature would seem to be an advantage. More extended observation and experiment with this grass is highly desirable.

Another species of *Paspalum*, having the same creeping habit, has been observed in several of the Southern States. It is the *Paspalum platycaule*. It is a grass of lower growth and smaller size than the preceding. It occurs in all the Gulf States, as well as in the West Indies and in South America. Mr. Benjamin Brodnax, of Morehouse Parish, Louisiana, has given a very full account of its habits in a Southern agricultural paper. He says the mode of growth is flat to the ground, taking root at every joint and spreading in every direction. It effectually kills

ut every other grass or weed, as it forms a thick sod and is evergreen. t looks like Bermuda grass and is equally prolific, but it possesses one rait that Bermuda grass does not, that is, it is easily got rid of. It s only necessary to plow shallow, turn the sod over, and in a week har- ow and your grass is gone. All grazing animals eat it in preference to ny other except Bermuda grass. It grows on a great variety of soil, ut thrives best in good soil. Some of the joints send up culms or stalks hich are very fine and wiry, with a few slender seed-bearing spikes at he summit. The runners extend out several feet, taking root at all the oints, which are usually only 1 or 2 inches apart. It grows too close to he ground and is too short for a good grass for hay, but for grazing it as many good properties. Like the preceding species, it should receive ttention from farmers, with careful experiments.

Paspalum setaceum is a species which is widely spread both in the orthern and Southern States. It grows usually 1½ to 2 feet high in ry, sandy, or gravelly soil, some forms having smooth and others very eavy leaves.. It seems to have very little practical value. (Plate 3.)

DIGITARIA.

This genus is usually considered as a section of the genus *Panicum*, ut it will be most convenient here to retain the old name. It serves to onnect *Paspalum* and *Panicum*, and in the structure of the flowers dif- rs from *Paspalum* very little except in commonly having an additional mpty glume to the spikelets. This glume in sometimes very small and ccasionally absent. The flowers or spikelets are arranged like those of *aspalum* on one side of a narrow flattened axis or spike, and there are everal spikes crowded together at or near the summit of the culm.

DIGITARIA SANGUINALE (*Panicum sanguinale*). Crab grass.

This is an annual grass, which, although a native of the Old World, as become spread over most parts of this country, and, indeed, over ost tropical countries of the globe. It occurs in cultivated and waste rounds, and grows very rapidly during the hot summer months. The ulms usually rise to the height of 2 or 3 feet, and at the summit have om three to six slender flower spikes, which are from 4 to 6 inches ng. The culms are bent at the lower joints, where they frequently ke root. This grass is well known to farmers and planters in the outh under the name of crab grass. Professor Killebrew, Tennessee, ays:

> It is a fine pasture grass, although it has but few base leaves and forms no sward, et it sends out numerous stems or branches at the base. It serves a most useful urpose in stock husbandry. It fills all our corn-fields, and many persons pull it out, hich is a tedious process. It makes a sweet hay, and horses are exceedingly fond f it, leaving the best hay to eat it.

Professor Phares, Mississippi, says that the corn and cotton fields re often so overrun with it that the hay which might be secured would

be more valuable than the original crop. It is some times mowed from between the rows, some times cut across the ridges with the corn.

Any good piece of ground that has had this grass matured on it the preceding year may be plowed and harrowed smoothly and then rolled in May, and it will soon be covered with a rich growth. If the season is favorable two mowings should be made.

Digitaria villosa is a very similar species of the Southern States, with a perennial, creeping rootstock, the stem decumbent and bent below at the hairy joints. The leaves with their sheaths are very hairy. The external glume of the flower is scarcely one-fourth as large as the upper ones. It probably is frequently confounded with the preceding, and has the same qualities. (Plate 4.)

PANICUM. (Panic grass.)

The botanical character of this genus are as follows: Flowers in spikes, racemes, or panicles. The spikelets consist of one perfect flower (the upper or terminal one in the spikelet), and usually a second male or rudimentary one below it. Outer empty glumes two, one of which is smaller than the other, often very small, rarely absent. The glume of the perfect flower and its palet are usually of a coriaceous or leathery texture, and obtuse or obtusish. The grasses belonging to this genus are extremely numerous, and of widely different general appearance. We have about fifty native species, most of which have little practical value except as adding more or less to the wild forage of our woods and fields. But some species, both native and foreign, are of the highest agricultural value. We shall notice a few of those which seem best adapted to cultivation in this country.

PANICUM JUMENTORUM. (Guinea grass.)

A large, vigorous, perennial grass, attaining in good soil a height of from 6 to 10 feet, the leaves are 1 to 2 feet long, and frequently an inch or more wide, rough on the edges, and with a few scattered hairs on the surface; the sheath is long and nearly smooth, except near the joints, which are soft-hairy. The panicle is from 1 to 1½ feet long and diffusely branched, the upper branches single and 3 to 4 inches long, the lower ones two to five together and 6 to 10 inches long; the flowers are thinly scattered along the rather slender branches nearly the whole length on slender, rather short pedicels. The spikelets are about 1½ lines long, smooth and rather acutely pointed; the lowest glume is about one-third the length of the spikelet; the second glume is slightly longer than the perfect flower and five to seven nerves. The lower flower is staminate or male only, the glume and palet thin, the upper flower perfect, much thicker, and finely wrinkled transversely.

This grass is a native of Africa, but has been introduced into many tropical countries, and in the West Indies is extensively cultivated for pasturage. It has been introduced in Florida, but is yet very little

known in the Southern States. It has been confounded with the Johnson grass, which is very different, and is botanically *Sorghum halapense.* It (the *Panicum jumentorum*) seldom matures seed in this country and may be propagated by dividing the roots or by obtaining the seed from foreign countries. The best time to set out the roots is in March and April. If so treated it is said that they will be ready for the first mowing by the last of May, and that with favorable weather mowing may be repeated about every six weeks until frost occurs. The roots are tender and easily killed by frost, and should therefore be protected by mulching during the winter. It is too tender to be cultivated except in the very warmest portions of our country. An analysis made at the Department of Agriculture in 1878 shows it to be very rich in nutritive materials. (Plate 5.)

PANICUM BARBINODE. (Para grass *P. molle Swz.* in Annual Report, 1883.)

This is quite similar in general appearance to the preceding, but has smaller leaves, and a shorter, less spreading panicle, with shorter, more densely-flowered branches. The spikelets are closer together and very short-pediceled, the lowest glume is about one-fourth as long as the spikelet. It is said to be a native of Africa. It has been introduced into South America, and in Brazil is largely cultivated for pasturage, and is said to be unequaled for the quantity and quality of the feed which it produces. Dr. Charles Mohr, of Mobile, Ala., states that it has been some years introduced in that vicinity, and that it is extremely productive and valuable. It has also been introduced in Florida. (Plate 6.)

PANICUM MILIACEUM. (Millet grass.)

This annual species grows 2 to 3 feet high, with a large, open nodding panicle of flowers. The stem is thick and branching above, the nodes or joints swollen, the leaves, and especially the sheaths, are soft hairy. The leaves are numerous and about 6 inches long. The flowers and seeds are at the ends of the slender pedicils, and when ripe become yellow in color. It is a native of Asia, where it has been cultivated for ages, and in many parts is an important article in the food supply of the natives. It is also cultivated in Egypt, Turkey, and Southern Europe. It has been cultivated to a limited extent in this country for forage, and will thrive and ripen in the Northern as well as the Southern States.

Mr. Charles L. Flint says:

Millet is one of the best crops we have for cutting and feeding green for soiling purposes, since its yield is large, its luxuriant leaves juicy and tender, and much relished by milch cows and other stock. The seed is rich in nutritive qualities, but it is very seldom ground or used for flour, though it is said to exceed all other kinds of meal or flour in nutritive elements. An acre well cultivated will yield from 60 to 70 bushels of seed. Cut in the blossom, as it should be for feeding to cattle, the seed is comparatively valueless. If allowed to ripen its seed, the stalk is no more nutritious, probably, than oat straw.

Of the native species of *Panicum* we will notice a few:

PANICUM TEXANUM. (Texas millet.)

This grass is a native of Texas, and was first described and named by Prof. S. B. Buckley in 1866. It is an annual, growing from 2 to 4 feet high, at first erect, then becoming decumbent and widely spreading, sparingly branched, very leafy, the sheaths and leaves soft hairy, the margin of the leaves rough, the blade of the leaf 6 to 8 inches long and one-half to 1 inch wide, the upper leaves reaching to the base of the panicle, or nearly so; the panicle is 6 to 8 inches long, strict or close, the branches alternate, erect, simple, 3 to 4 inches long, with somewhat scattered sessile spikelets. The branches of the panicle are rough, the pedicels with scattered hairs, especially near the flowers; the spikelets are oblong, somewhat pointed, 2 to 2½ lines long, sparsely hairy, the lower glume is half or two-thirds the length of the upper one, acute, five-nerved, the lateral nerves uniting with the mid-nerve below the apex, the upper empty glume prominently five to seven nerved, pointed, the flowering glume of the sterile flower is five to seven nerved, its palet thin and transparent, as long as the glume, the perfect flower ovate or oblong-ovate, acutish, transversely wrinkled with fine reticulated lines.

It is a grass of rapid, vigorous growth, many stalks proceeding from the same root, growing very close and thick at the base, succulent, and yielding a large amount of forage.

Mr. Pryor Lea, of Goliad, Tex., has had it in cultivation a number of years, and states as follows:

> I consider it far superior to any grass that I ever saw for hay. It is a much more certain crop than millet, and cultivated with less labor, and all kinds of stock prefer it. In this region it is regarded, in the condition of well-cured hay, as more nutritious than any other grass. It grows only in cultivated ground; it prospers best in the warmest season of the year; its luxurious growth subdues other grasses and some weeds, with the result of leaving the ground in an ameliorated condition.

Mr. H. W. Ravenel, of Aiken, S. C., says he has been cultivating *Panicum Texanum* for several years. It is hardy and naturalized there, freely seeding and propagating itself, coming up in his grounds with other grasses, and much larger and better than any of them for hay and forage.

The experiments of Professor Phares and others, in Mississippi, substantially confirm the statements of Mr. Lea, although it is said that it will hardly hold its own against the common crab grass (*Digitaria sanguinale*). It has been called concho grass in some parts; in other Colorado bottom grass. It is stated that on the Colorado bottoms, Texas, many of the farmers have devoted their farms entirely to its production, finding it more profitable than corn or cotton. It is cut twice and sometimes three times in a year, yielding about one and a half tons per acre at each cutting. (Plate 7.)

PANICUM PROLIFERUM.

This species has a wide range of growth, being found in the Northern and Western as well as the Southern States, growing late in the season, generally in low waste grounds. The stems are flattened, erectish, or decumbent, spreading and rooting at the lower joints. It is a useful grass as helping out the supply of wild fodder, but does not present particular promise for cultivation. But in the Southern States, from South Carolina westward, there occurs a variety of this grass, called *Panicum proliferum*, var. *geniculatum*, or sprouting crab grass.

It is an annual, growing in low moist ground. The stems are at first erect, then becoming decumbent and spreading, frequently attaining a length of 6 or 7 feet, bent and rooting at the lower joints. It has much the same habit as the *Panicum texanum*, but the stems are more flattened and smoother; the leaves are smoother and longer. The stems are sometimes nearly an inch thick at the base and very succulent. The leaves are sometimes 2 feet long and half to three-fourths of an inch wide. The lower joints give out numerous branches, which develop flowering panicles that are partly inclosed in the large leaf-sheaths. The main stem is also terminated by a diffuse panicle sometimes 2 feet long. Large specimens have a handsome appearance. The spikelets are pale green, rarely purplish, about one line long. The neutral flower is a little longer than the perfect one, the lower empty glume broad and short, the upper acute and strongly seven-nerved. Mr. Charles Mohr, of Mobile, says of it:

> In damp grassy places it prefers rich ground throughout the coast region. It commences to vegetate vigorously in the hottest part of the summer, throwing out numerous shoots from the joints, forming large-branched bushes. The foliage is rich and tender, and the succulent, thick stems are sweet and juicy. After cutting, it throws out numerous sprouts from the lower joints, which grow rapidly, so as to allow repeated cuttings until frost. It is through all stages of its growth much relished by horses and cattle.

(Plate 8.)

PANICUM AGROSTOIDES. (Red-top Panicum.)

This is a perennial grass, commonly growing in large clumps in wet meadows or on the muddy margins of lakes and rivers. It grows 4 to 6 feet high, is erect in habit, and develops its reddish panicles from several of the joints as well as at the apex. The stem is somewhat flattened and very smooth, as are the sheaths; the leaves are 1 to 2 feet long, about half an inch wide, and somewhat rough on the margins and midrib. The terminal panicle is 6 to 12 inches long, at first somewhat close, but becoming quite open and diffuse. The lateral panicles are shorter and partly inclosed by the sheath at the base. The branches of the panicle are mostly 1 or 2 inches long, and rather densely flowered nearly to the base. The spikelets are a little more than a line long, on very short pedicels, mostly racemose on one side of the branches, oblong, acute, the lower empty glume ovate, acute, half as long as the

upper one, which is rather long-pointed and five-nerved; the lower sterile flower is a little shorter than the longer glume and a little shor than the perfect flower, which is oblong, obtuse, and under a lens sho a few beards at the apex. This grass produces a large amount of f age which makes fair hay if cut before flowering time; if left late contains too many wiry stalks. It may be utilized as a hay crop in l grounds, but it is doubtful if it can be made productive on dry, tillab land. (Plate 9.)

PANICUM ANCEPS. (Two-edged Panic grass.)

A perennial grass, when well developed resembling the preceding but of a smaller, lighter growth, generally found in moist clay soil. has a flattish erect stem, 2 to 3 feet high, with smooth leaves a foot more long, of a bluish-green color, and mostly near the base of the ste The rhizoma, or root-stock, is thick, scaly, and creeping near the surfa of the ground. The panicle is 6 to 12 inches long, with short branch near the top, the lateral branches 3 to 6 inches long, rather distan erect or somewhat spreading. Usually there are also several small lateral panicles from the upper joints of the culm. The spikelets ar about a line and a half long, a little longer than those of *Panicum agrostoides*, oblong, lanceolate, a little curved, and sessile, or on very short pedicels. The lower empty glume is broadly ovate, and about hal as long as the five to seven nerved upper one. The lower glume of th sterile flower is as long as the upper empty glume and much like it i texture, while the palet is thin, obtuse, and much shorter. The perfect flower is one-third shorter than the upper empty glume, oblong; the flowering glume and its palet, as in most species of *Panicum*, is thick and hard in texture. This cannot be considered a valuable grass, but it frequently occurs in neglected and poor land in sufficient quantity to afford considerable grazing for stock. It makes its growth late in the season, usually reaching the flowering stage in August. Dr. Mohr, of Mobile, remarks that it is not much relished by stock, being rather harsh and dry.

Professor Phares says it forms strongly-rooted spreading clumps, often completely carpeting the ground with very pretty, glossy, light-green foliage. (Plate 10.)

PANICUM CRUS-GALLI. (Barn-yard grass.)

This is an annual grass, with thick, stout, erect, or procumbent culms, usually 2 to 4 feet high, and branching at the base. The leaves are long, sometimes 1 to 1½ feet, and half an inch to an inch wide, rough on the margins, the sheaths sometimes hairy, sometimes smooth, and the lower ones much thickened at the base. The panicle, like the entire plant, is variable in size, sometimes 3 inches, sometimes a foot or more long, lanceolate in outline, and composed of a number of alternate, mostly simple, rough branches, or frequently the branches are glomerate and much

subdivided. The panicle is, in different varieties, narrow and with few short, simple branches, or large and dense with long and spreading branches. The glumes are also variable, being sometimes awnless and sometimes provided with long, rough awns or beards. These variable features have been indicated by special names, as variety mutica, the form without beards; var. *hispida*, a form with rough, hairy-leaf sheaths; variety *echinata*, a form with long, rough awns to the glumes. The spikelets are densely crowded on the spikes or branches of the panicle. The glumes are usually more or less rough, with oppressed, stiff hairs, the outer empty one very broad, with a very short point one-third as long as the pointed upper one, the glume of the sterile flower still longer and frequently having a long, strong awn sometimes an inch or more in length. The perfect flower is ovate, smooth, pointed, and contains a large flattened orbicular seed. This grass is found in almost all parts of the world. It is frequently found in barn-yards, and hence the common name.

In the Northern States it is esteemed as a rough, coarse weed; in the South it is often utilized and considered a very useful grass.

Dr. Charles Mohe, of Mobile, says of it:

An annual, 2 to 3 feet high, bearing its roughly-awned flowers in dense, one-sided panicles, composed of numerous crowded spikes; it grows luxuriantly, particularly in the lowlands of the coast; is greedily eaten by horses and cattle, and makes a hay of good quality. It is justly regarded as an excellent grass, particularly before it ripens its seed, as in the latter stages of its growth the long and stiff awns of its spikes tend to make it somewhat unpalatable.

Professor Phares, of Mississippi, says:

In Louisiana, Mississippi, and some other States it is mowed annually. Some farmers assure me that they harvest four or five tons of hay per acre. It may be cut twice each season by making the first mowing as soon as it begins to bloom. I know no one who plants it; but it annually reseeds the ground and requires no cultivation or other care, save protection from live stock and the labor of harvesting. Being a coarse grass, with long leaves and large succulent stems, it requires care to cure well. In one county in Mississippi hundreds of acres are annually mowed on single farms. Cows and horses are very fond of it, whether green or dry. Farmers who have tested it most thoroughly for many years prefer it to the best corn fodder.

(Plate 11.)

PANICUM VIRGATUM L. (Tall Panic grass; Switch grass.)

A tall perennial grass, 3 to 5 feet high, growing mostly in clumps in moist or even in dry sandy soil, very common on the sea-coast, and also in the interior to the base of the Rocky Mountains. The culms are erect, firm, and unbranched; leaves 1 to 2 feet long, flat, rough-margined, otherwise smooth, one-third to one-half inch wide. The panicle is large and diffuse, rather pyramidal, from 6 inches to 2 feet long, the branches angular, rather verticillate, the lower in fives or more, decreasing above, flowering mostly near the extremities. The lower branches are frequently half as long as the panicle and much subdivided. The

spikelets are usually short-stalked, variable in size, but usually about two lines long, ovate, sharp-pointed, commonly purplish. The lower empty glume is from half to two-thirds as long as the upper, both are pointed, sometimes long pointed; the lower glume is three nerved, the upper one five to seven-nerved; the lower flower is male, nearly as long as the upper glume, its glume five to seven-nerved and acute, its palet one-quarter shorter, thin, two-nerved. The perfect flower is shorter than the lower one, smooth, oblong, and obtuse. This is a good and prolific grass if cut when young; when ripe it becomes harsh and unpalatable. It forms a constituent of the native grasses of the prairies, particularly in moist localities. (Plate 12.)

PANICUM DIVARICATUM. (Cane-like Panicum.)

A tropical and subtropical species found in our country only in Florida and the Gulf States near the coast. It is a shrubby plant, the culms being woody and persistent, like the small kind of cane. Only the leaves and young shoots are eaten by cattle. The larger stems are of the size of a goose quill. It is smooth and decumbent, with short, spreading branches. The leaves are lanceolate, 2 to 3 inches long by four to five lines wide, gradually pointed. The panicles terminate the branches, are 2 to 4 inches long, with comparatively short divergent branches and few flowers. The spikelets are obovate, tumid, about two lines long, smooth. In the districts where it grows this grass may be utilized, as an analysis of its composition gives a very good result. (Plate 13.)

PANICUM GIBBUM.

A perennial species, growing in swamps and low wet ground in the Southern States, from North Carolina to Florida and to Texas. The stem is decumbent, branching, and rooting at the lower joints. The panicle is 3 to 5 inches long, and narrow from the erect, appressed branches. The spikelets are oblong or lance-oblong, rather obtuse, although narrowed above. The lower glume is small, about one-fourth as long as the upper one, which is strongly eleven-nerved, swollen at the base, and twice as long as the smooth, fertile flower. The leaves are smooth or rarely somewhat hairy, half an inch broad and 6 to 8 inches long. The whole plant is of a deep green color. The flowers drop off soon after flowering. This grass, if it occurs in abundance, would be of considerable value, as it furnishes a good deal of nutritious matter. (Plate 14.)

PANICUM OBTUSUM. (Obtuse-flowered Panicum.)

A perennial species of Texas, New Mexico, and Arizona. It has a strong, running root-stock, which at intervals sends up flowering culms, which are about 1½ to 2 feet high, very smooth, pale green, with numerous smooth, narrow, erect, stiff, long-pointed leaves, and a narrow linear panicle, 3 to 4 inches long, composed of about half a dozen

short, alternate, sessile branches, the lowest about an inch in length, the upper very short, and all densely crowded with the sessile flowers. The two outer glumes are of nearly equal length, or the lower one rather the longer, which is different from the ordinary rule of the genus. They are obtuse, five to seven-nerved, and fully as long as the male or sterile flower, which is also obtuse. The perfect flower is of equal length with the sterile one, very smooth, shining, delicately striate longitudinally, and obtusish. Leafy runners, 2 to 3 feet long, are sent out form the base, which at intervals form thickened woolly knots or nodes which eventually take root. This grass will evidently have great endurance of drought, and is deserving of trial with reference to its agricultural value.

PANICUM CAPILLARE. (Old Witch grass; Hair-stalked Panic grass.)

An annual grass varying in height from 6 inches to 2 feet, often branching at the base. It has a large terminal panicle, which, when mature, is very diffuse, with long capillary branches. The leaves and sheaths are usually covered with long spreading hairs. It is very common in cultivated grounds, making its growth late in the summer, and after maturity the tops break off and are blown about and accumulate in quantities in fence corners. There is a smoothish form growing in Texas and the Western Territories. The grass is generally rejected by cattle, especially the very hairy forms. It is one of the most worthless kinds. (Plate 15.)

There are many other species of *Panicum* which have some value as wild forage where they prevail, but they are generally scanty in foliage, thin in habit of growth, or otherwise unsuitable for cultivation.

SETARIA.

The structure of the flowers in this genus is the same as in *Panicum*, of which genus it is by some botanists considered only a section. It is characterized as follows. The spikelets collected into a cylindrical or elongated spike-like, or sometimes interrupted, panicle. Below the articulation of the spikelets are several (or one) bristles or stiff hairs, which are supposed to be abortive branchlets, and which are persistent after the fall of the spikelets.

SETARIA ITALICA. (Hungarian grass, Italian Millet, German Millet.)

This grass is supposed to be a native of the East Indies, but it has been extensively introduced into most civilized countries. It has long been cultivated as a fodder grass both in Europe and in this country. It is an annual grass of strong rank growth, the culms erect, 2 to 3 feet high, with numerous long and broad leaves, and a terminal, spike-like, nodding panicle, 4 to 6 inches long, and often an inch or more in diameter. The panicle is composed of a great number of small closely-crowded branches, each of which consists of a small group of several

clusters of spikelets, at the base of each of which there springs two or three bristles, sometimes short and sometimes so long as to give the head a very bristly appearance. The bristles are roughened or barbed by numerous teeth-like processes on the margin, pointing towards the apex. The spikelets are about 1 line long; the lower glume is about one-third as long as the upper one, which, with the glume of the sterile flower, is obtusish and about the length of the perfect flower. There is a great difference in the different varieties and forms of this grass, so much so that some of them have been considered different species, but the general opinion of botanists is that they are all varying forms of the same species, dependent upon the character of the soil, thickness of seeding, moisture or dryness, and time of sowing. It owes its value as a fodder plant to the abundance of its foliage and to the large quantity of seed produced. In some instances objection has been made to this grass on account of the bristles which surround the seed, and which have been said to penetrate the stomachs of cattle so as to cause inflamation and death. But it is plain that this opinion is not generally held, as the cultivation of the grass is widely extended and everywhere recommended.

For forage it should be cut as soon as it blooms, when of course, it is worth nothing for seed, but is most valuable for forage and exhausts the land much less. If left for the seed to mature they are very abundant and rich feed, but the stems are worthless while the soil is more damaged. The matured stems are very hard, indigestible and injurious, and the ripe seeds will founder more promptly than corn, and sometimes produce diabetes if mouldly and too freely used. If cut at the right stage the whole plant is a safe and very valuable forage. On good soil if the ground be moist it will be ready for mowing in sixty days from seeding and produce from two to four tons of hay per acre. It is folly to sow it on poor land.—Professor PHARES.

(Plate 16.)

SETARIA SETOSA. (Bristle grass, Fox tail.)

A native species growing in New Mexico, Texas, and southward into Mexico and South America. It grows about 2 feet high. The stem and leaves are smooth except a fine hairy ring at the joints. The leaves are 6 to 10 inches long, narrow, and gradually tapering to a long point. There is a tuft of short white hairs at the top of the leaf sheath. The panicle is 4 to 6 inches long, erect or slightly nodding at the top, narrowly cylindrical with very short sessile branches, usually somewhat interrupted below, sometimes the lower branches are longer and the panicle looser. It has much the appearance of the other species which we called Pigeon grass. The axis of the panicle is scabrous. The lower glume is broadly ovate, more than half as long as the upper, clasping the base of the spikelet, three-nerved, acute, the margins scarious and minutely pubescent; the upper glume is also broadly ovate, short-pointed, five-nerved, about as long as the perfect spikelet; the glumes of the sterile flower are much like the upper empty glumes and also five-nerved; its palet is about two-thirds as long as the glume, and much narrower;

the perfect flower is oblong, very finely striate and dotted. The bristles are variable in length, about one to each spikelet, usually three to four times as long as the spikelet.

We know little as to the agricultural value of this species; as it is found in the arid districts it is deserving the attention of farmers of that section. (Plate 17.)

SETARIA GLANCA. (Pigeon grass, Bottle grass.)

A native of most tropical and many temperate climates, and has been introduced into most cultivated fields, springing up or growing after the cutting of wheat and early grain, and making its growth in the latter part of the season. It is generaly an annual, but southward it assumes a perennial form. It grows about 2 feet high, with leaves 6 to 9 inches long, one-fourth to one-third of an inch wide, and generally smooth. The panicle is terminal, cylindrical, 2 to 3 inches long, and about one-third of an inch wide, dense and spikelike from the numerous, approximated short branches or clusters of flowers. These clusters consist of from one to three spikelets, having at the base of each a cluster of from six to ten bristles, which are two to four lines long, and finely barbed upwardly. When mature they assume a tawny yellow color. The spikelets are a little over a line long, oblong; both the outer glumes are short and broad, the lower one third and the upper two-thirds as long as the flower; the glume of the male or lower flower is broadly ovate, obtusish and five-nerved, its palet is of equal length and two-nerved; the perfect flower is oblong, beautifully striated longitudinally, wrinkled and dotted transversely. This grass is often found with the next (*S. Viridis*), in stubble fields, and furnishes a considerable amount of fodder, which is as nutritious as Hungarian grass, but not as productive. The figure (Plate 18) does not represent a sufficient quantity of bristles.

SETARIA VIRIDIS. (Green Pigeon or Foxtail.)

This species has the general habit and appearance of the preceding; it differs in the commonly looser, longer, and more tapering, less erect spike, in the smaller spikelets, shorter lower glume, less distinctly transversely wrinkled seed, and in fewer bristles, which are of a greenish color. It grows in the same situations and commonly with the preceding. The seeds of both kinds are eagerly sought for by birds and poultry, especially among the stubble after harvesting wheat.

PENICILLARIA SPICATA. (African cane, Egyptian Millet, East India Millet, Cat-tail, and Pearl Millet.)

A tall, erect, thick-stemmed grass. It grows to the height of 6 feet or more, and the stock is terminated by a compact, dense, cylindrical spike resembling the common cat-tail, frequently a foot long and an inch in thickness, which is studded with the small obovate sessile grains, surrounded at the base by an abundance of short, coarse hairs or bristles.

This millet has been more or less cultivated, especially in the Southern States, for many years. On rich ground it is said to yield an immense amount of forage, for which purpose it should be cut before it has matured, and may be cut many times during the season. It is extensively cultivated in India and there forms an important article of food for the natives.

SPARTINA.

A genus of coarse, perennial grasses, growing mainly in marshy ground, from extensively-creeping, scaly root stocks. The leaves are long and tough and the sheaths smooth. The flowers are produced in racemed spikes, the spikes varying in size and arrangement in different species. The flowers are arranged in two ranks on one side of a triangular axis, being closely sessile and more or less imbricated. The spikelets are one-flowered, much flattened laterally. The outer glumes are strongly compressed and keeled, acute or bristle-pointed, the keel mostly rough-hispid, the upper one longer and larger than the obtusish flower. The flowering glume is strongly compressed and is shorter than the thin membranaceous palet. There are about five species in the United States.

SPARTINA CYNOSUROIDES. (Fresh-water Cord grass, Fall Marsh grass.)

This species has a wide range, from near the coast to the Missouri River. In the Western States it is very plentiful, often forming a large part of the grass of the sloughs and wet marshes of that region. It is coarse and stout, growing from 3 to 5 feet high, with leaves 2 to 3 feet long. The top of the culm for about 1 foot is occupied by from five to ten flower spikes, which are from 1½ to 3 inches long, and the spikelets are very closely imbricated. The outer glumes are unequal, the lower one linear-lanceolate, the upper one lanceolate, with a long, stiff point. The flowering glume is about as long as the lower glume, the upper half of the stout keel strongly hispid. The palet is thin membranaceous, two-nerved, and longer than its glume.

This grass is frequently cut for hay, but it is a very coarse, inferior article, unless cut when very young. It gives good feed very early in the spring, but becomes so coarse as soon to be rejected by the cattle when anything better is procurable. In the bottom lands of the Mississippi it is abundant, and has to some extent been manufactured into paper. (Plate 19.)

SPARTINA JUNCEA. (Marsh grass, Salt grass, Rush salt grass.)

A slender, rigid grass, usually 1 to 2 feet high, from a creeping, scaly rhizoma; leaves involute, rush-like, and rigid; panicle composed of three to five linear, alternate, shortly-peduncled, spreading spikes 1 to 2 inches long and an inch or more distant on the culm. The spikelets are crowded. The outer glumes are very unequal, acute, the upper one

linear-lanceolate, strongly compressed, and keeled, four or five lines long, the margins membranaceous, the middle thick, and the keel scabrous; the lower one is less than half as long as the upper, narrow and thin. The flowering glume is about four lines long, lanceolate, obtuse, membranaceous, compressed, and with a thick midrib which is roughish near the apex; the palet is thin, as broad and somewhat longer than its glume. This grass forms a large portion of the salt marshes near the sea-coast. It makes an inferior hay, called salt-hay, which is worth about half as much per ton as timothy and red-top. (Plate 20.)

TRIPSACUM DACTYLOIDES. (Gama-grass, sesame-grass.)

A tall, perennial grass, found both North and South, with solid culms from thick creeping rhizomes, broad and flat leaves, and with flower spikes 4 to 8 inches long produced from the side joints and from the top, either singly or two or three together. The upper portion of these spikes is staminate or male, and the lower portion pistillate and producing the seeds. The upper or male portion of the spikes drops off after flowering. The fertile portion is much thickened, somewhat flattened and angled, and the fertile flowers and seeds are deeply embedded in it. This part of the spike at maturity easily breaks up into short joints. The staminate flowers are three to four lines long, sessile, and in twos at each joint of the axis. Each spikelet is two flowered, the outer glumes are somewhat thick and coriaceous, oblong, the lower one obscurely many-nerved, the upper one of thinner texture, boat-shaped, five-nerved and scarious-margined; the flowering glumes and palets are equal in length to the outer glumes, very thin and membranaceous, awnless; the anthers open by two pores at the apex. The pistillate spikelets are single at each joint; also two-flowered; the outer empty glume is ovate, cartilaginous-thickened, the inner glume much thinner, and pointed. One of the flowers is neutral, the other fertile, the flowering glumes and palets very thin and scarious. The stigmas are long, purple, and feathered. Mr. Howard, in the Manual of Grasses for the South, says:

> This is a native of the South, from the mountains to the coast. The seed stem was up to the height of 5 to 7 feet. The seeds break off from the stem as if from a joint, a single seed at a time. The leaves resemble those of corn. When cut before the seed stems shoot up they make a coarse but nutritious hay. It may be cut three or four times during the season. The quantity of forage which can be made from it is enormous. Both cattle and horses are fond of the hay. The roots are almost as large and strong as cane roots. It would require a team of four to six oxen to plow it up. It can, however, be easily killed by close grazing, and the mass of dead roots would certainly enrich the land. As the seeds of this grass vegetate with uncertainty, it is usually propagated by setting out slips of the roots about 2 feet apart each way. On rich land the tussocks will soon meet. In the absence of the finer hay grasses this will be found an abundant and excellent substitute. The hay made from it is very like corn fodder, is quite equal to it in value, and may be saved at a tithe of the expense.

This account is concurred in by other writers. (Plate 21.)

EUCHLŒNA LUXURIANS. (Teosinte, Guatemala grass.)

This grass is a native of Mexico and Central America, but has been introduced into cultivation in various parts of the world, and recently in the Southern States. It is closely related to Indian corn (*zea mays*). It has the male flowers in a tassel at the top of the stalk. The fertile flowers are from the lateral joints, not like maize, on a thickened axis, but on a very slender stem, and inclosed in a loose external husk.

Prof. Asa Gray writes in the American Agriculturist for August, 1880, respecting this plant, as follows:

The director of the botanic garden and government plantations at Adelaide, South Australia, reports favorably of this strong-growing corn-like forage plant, that the prevailing dryness did not injure the plants, which preserved their healthy green, while the blades of other grasses suffered materially. The habit of throwing out young shoots is remarkable, sixty or eighty rising to a height of 5 or 6 feet. Further north, at Palmerston (nearer the equator), in the course of five or six months the plant reached the height of 12 to 14 feet, and the stems on one plant numbered fifty-six. The plants, after mowing down, grew again several feet in a few days. The cattle delight in it in a fresh state, also when dry. Undoubtedly there is not a more prolific forage plant known; but as it is essentially tropical in its habits, this luxuriant growth is found in tropical or subtropical climates. The chief drawback to its culture with us will be that the ripening of the seed crop will be problematical, as early frosts will kill the plant. To make the *Teosinte* a most useful plant in Texas and along our whole southwestern border, the one thing needful is to develop early-flowering varieties, so as to get seed before frost. And this could be done without doubt if some one in Texas or Florida would set about it. What it has taken ages to do in the case of Indian corn, in an unconscious way, might be mainly done in a human life-time by rightly-directed care and vigorous selection.

ZEA MAYS. (Indian corn.)

This plant is too well known to need more than a botanical description. The staminate or male flowers are produced at the apex of the stalk in a large, branched panicle, a foot or more in length. The branches of the panicle are rather slender, 8 to 10 inches long, with a few shorter subbranches near the base. They are flower-bearing through their entire length. The flowers are in small clusters of two to four spikelets at each joint of the flattened axis, on very short, slender pedicels, or some of them almost sessile, the different clusters somewhat overlapping each other. The spikelets are each four to five lines long and two-flowered. The outer glumes are membranaceous, lanceolate, and acute or acuminate, sparsely hairy, five to nine nerved, and delicately purple striped. The flowering glumes and palets are nearly as long as the outer glumes, lance oblong, alike in texture, very thin membranaceous, the glume three-nerved, the palet two-nerved, both delicately fringed on the margins near the apex with soft white hairs. Stamens, three in each flower.

The female or pistillate flowers are produced from lateral joints of the stem on a hard, thickened, cylindrical spike or axis, called the cob, in longitudinal rows (usually eight to sixteen). The spikelets are closely sessile and packed in the rows. The structure of the spikelets is some-

what obscure. The glumes and palets are reduced to a few scales at the base of the large grain, and are usually unnoticed. At the apex of each grain is produced a long thread-like style, varying from a few inches to a foot long. The entire axis, or ear of corn as it is called, is enwrapped by a number of leaf-like bracts, commonly called the husks. The long thread-like styles extend beyond and protrude from the point of this envelope, where they may be fertilized by the pollen falling upon them from the male flowers in the terminal panicle. There is a variety of maize in which each kernel or grain of the corn is enveloped by a husk of three or four pieces three-fourths of an inch to 1 inch long. It is supposable that these are the normal envelopes, which in other varieties have become abortive.

ZIZANIA AQUATICA. (Wild rice, Indian rice, Water oats.)

This grass is botanically related to the common commercial rice (*Oryza sativa*), but is very different in general appearance. It is widely diffused over North America, and is found in Eastern Siberia and Japan. It grows on the muddy banks of rivers and lakes, both near the sea and far inland, sometimes in water 10 feet or more deep, forming patches or meadows covering many acres or extending for miles. Its ordinary growth is from 5 to 10 feet high, with a thick spongy stem and abundant long and broad leaves. The panicle is pyramidal in shape, 1 to 2 feet long, and widely branching below. The upper branches are rather appressed and contain the fertile flowers, and the lower branches contain only staminate ones. The spikelets are one-flowered, each with one pair of external husks or scales, which are by some botanists called glumes, and by others called palets. These husks or glumes in the fertile flower are nearly or quite an inch long, with an awn or beard as long or twice as long. The grain inclosed between them is half an inch long, slender, and cylindrical. The glumes of the staminate flowers are about half an inch long and without awns, each flower containing six stamens. These flowers fall off soon after they expand. The fertile flowers also drop very readily as soon as the grain is ripened. The grass abounds in the small lakes of Minnesota and the Northwest, and is there gathered by the Indians for food. The husk is removed by scorching with fire. It is a very palatable and nutritious grain. Some attempts have been made to cultivate the grass, but the readiness of the seed to drop must interfere with a successful result. Near the sea-coast multitudes of reed birds resort to the marshes where it grows and fatten upon the grain. The culms are sweet and nutritious, and cattle are said to be very fond of the grass. (Plate 22.)

LEERSIA.

A genus of rough-leaved grasses growing for the most part in marshy or moist ground throughout nearly all parts of the United States. There are about five species, two of which are confined to the Southern

States; the others, at least two of them, are very common, though rarely occurring in great quantity. They are sometimes cut for hay. They cannot be recommended for culture, but may be utilized wherever they grow spontaneously. The flowers grow in spreading panicles. The spikelets are sessile, on short one-sided branches or spikes. The spikelets are one-flowered, possessing but two scales, which may be called glumes or palets, which are strongly compressed, without awns, bristly ciliate on the keels, the lower one broader and inclosing the seed. Stamens, one to six; stigmas, two; grain flattened. The two common species are:

1. LEERSIA ORYZOIDES. (White grass, Cut grass, False rice.)

This is a handsome grass, the culms decumbent. It is commonly called rice grass, from its strong resemblance to common rice. The leaves are pale green, frequently a foot or more long, prominently veined below, very rough on the margins and on the sheaths. The panicle is about 1 foot long, diffusely branched, the branches mostly in twos, and an inch or two distant. The spikelets are very flat, about two lines long, nearly sessile, and mostly toward the ends of the long branches. The glumes are unequal, the lower one much the broader; the palets are wanting. The leaves are so rough on the margins as readily to cut the hand if roughly drawn through it.

2. LEERSIA VIRGINICA. (Small-flowered White grass.)

In this species the panicle is much smaller and narrower, and the branches appressed. The spikelets are smaller, the glumes narrower and smoother, and there are but two stamens. The leaves are narrower and smoother than in the first.

HILARIA JAMESII.

This grass was formerly called *Pleuraphis Jamesii*. It is a native of the arid regions extending from Mexico to Colorado, growing in clumps from strong, scaly runners or rhizomas. The base of the culm is usually covered with the dried leaves of the preceding year. The culms are from 1 to 1½ feet high, with a few short, rigid, light green, or bluish green leaves, which are more or less involute. Each culm is terminated by a simple, loose spike, 1 or 2 inches long, with alternate clusters of sessile spikelets. These clusters are quite complex in structure, each one containing three spikelets, one central and two lateral. The central spikelet consists of a single fertile flower, and the lateral spikelets each of two male flowers. The lower glume in each lateral spikelet is awned about the middle. The two outer glumes of the central spikelet are bifid or two-lobed, strongly nerved, and with the nerves extended into awns reaching beyond the apex of the glume

We do not know to what extent this grass prevails, nor what may be its agricultural value. (Plate 23.)

ANDROPOGON.

There are numerous species of this genus. They are perennial grasses, mostly tall, and with tough, wiry stems. Some of them occur in nearly all parts of the country from New England to Florida and west to Arizona. They are most abundant, however, in the Southern States, where they have been employed for permanent pastures. When they occur in quantity they can be utilized, but to be of value they should be kept from sending up their strong stems as these are universally rejected by cattle and horses. They are not to be recommended for cultivation, but their place should as soon as possible be supplanted by more valuable grasses.

We will mention the more common kinds:

1. ANDROPOGON VIRGINICUS. (Broom grass, Broom sedge.)

This species has an extended range on the eastern part of this continent, growing in a great variety of soils and situations, but mostly on dry hills, abandoned fields, or stony woods and pastures. The culms are from 2 to 4 feet high, and very leafy; the leaves two-ranked at the base, smooth except a few long hairs on the margins and at the throat of the sheath. The panicle is long, narrow, and leafy, 1 to 2 feet long, composed of numerous lateral branches from the upper joints. These branches are several times subdivided and partly inclosed in the long-leaf sheath, each ultimate sheath or bract inclosing usually a pair of loose, slender flower spikes. These spikes are about 1 inch long, comprising ten or twelve joints, each joint giving rise to one sessile fertile spikelet, and a hairy pedicel longer than the fertile flower, at the summit of which there is the vestige of a flower, or a mere bristle-like point. The fertile spikelets are one-flowered and consist of two outer thickish glumes and two thin transparent inner ones, one of which has a slender awn three or four times its own length; the upper one is by some considered as a palet, and is not awned. (Plate 24.)

2. ANDROPOGON SCOPARIUS. (Wood grass, Broom grass.)

This grass usually grows from 2 to 3 feet high, the flowering spikes coming out in small clusters from many of the side joints on slender, graceful peduncles. The spikes have a small bract near the base, and consist of a slender axis, with from six to ten alternate joints. At each joint there is one sessile, fertile spikelet, and a flatttened hairy pedicel or stalk nearly as long as the fertile spikelet, and at its apex a rudimentary flower, consisting of a single awned glume. The fertile spikelet has two outer, empty, narrowly lanceolate glumes, about four lines long. The flowering glume is very thin, and furnished with a twisted awn twice as long as the flower. The palet is also very thin and shorter than its glume.

Mr. Charles Mohr, of Mobile, says of this grass:

One of our most common grasses, covering old fields and fence-rows, and extensively growing in the dry sandy soil of the pine woods. Much despised as it is as a trouble-

some, unsightly weed, it has its good qualities, which entitle it to a more charitabl consideration. In the dry pine woods it contributes, while green and tender, a larg share to the sustenance of stock.

(Plate 25.)

3. ANDROPOGON MACROURUS. (Heavy topped Broom grass.)

This species is frequent on low sandy ground near the coast, fro New Jersey to Florida and thence westward to Texas. It has a sto culm 2 to 3 or even 4 or 5 feet high, bushy branched at the summi loaded with numerous flower-spikes, which form thick leafy cluste The spikelets have the same general structure as the preceding. Th fertile flower has a capillary awn three or four times as long as its glum and the sterile flower, which is usually present in the genus, is reduce to a mere point at the apex of th e slender plumose pedicel. (Plate 2

4. ANDROPOGON FURCATUS. (Finger-spiked Broom grass, Blue Ste

This is the tallest of our species. It grows erect to the height o or 6 feet, in rocky or hilly ground, or at the West it is abundant on t native prairies, where it is frequently called blue stem. The leaves a long and frequently somewhat hairy on the sheaths and margins. T spikes are in small clusters of three to six, terminating the stalk, a also several clusters from the side branches. The spikes are usuall to 3 inches long, rather rigid, and contain ten to twenty points ea At each joint there is one sessile, perfect flower, and one stalked o which is male only, otherwise it is nearly like the fertile one. T outer glumes are about 4 lines long, the upper ones tipped with a sh stiff awn. The flowering glume of the perfect flower is twisted a about one-half inch long.

This species, as above stated, is abundant on the prairies of the We where it is one of the principal hay grasses of the country, and is exte sively cut and cured for winter use. (Plate 27.)

CHRYSOPOGON NUTANS. (Indian grass, Wood grass.)

This is a near relative of the *Andropogons;* is also related to t genus *Sorghum*, and is known in the botanical works as *Sorgh nutans*. It is a tall, perennial grass, having a wide range over all t country east of the Rocky Mountains. It grows rather sparsely a forms a thin bed of grass. The stalks are 3 to 4 feet high, smooth, h low, straight, and having at the top a narrow panicle of handsome str colored or brownish flowers, 6 to 12 inches long, which is gracef drooping at the top. The spikelets are at the ends of the slen branches of the loose panicle, generally of a yellowish color. At base of each spikelet are two (one on each side) short, feathery pedic the flowers which they are supposed to have been made to support h entirely disappeared. The outer glumes are about three lines lo both alike lanceolate, obtusish, coriaceous five to seven nerved, lower one sparsely hairy, and with hairs at the base and on the st below.

Within the outer glumes are two thin hyaline glumes, one nearly as long as the outer glumes, and a shorter one with a twisted and bent awn half an inch or more in length. The true palet is very minute or wanting.

This grass when it occurs in quantity is frequently utilized for hay making, for which purpose it should be cut early. There are three other species occurring in the Southern and Southwestern States not of much value in an economic view. (Plate 28.)

SORGHUM HALAPENSE. (Cuba grass, Johnson grass, Means grass, False Guinea grass, Evergreen millet, Arabian millet.)

A tall perennial grass, with strong, thick, undergrowing root-stocks, and an abundance of long and wide leaves. Its stems attain a height of 5 or 6 feet, with a large and spreading panicle. In botanical characters it does not differ much from the preceding genus, except in habit and in the flower glumes becoming more hardened after flowering. The panicle when well developed is a foot or more in length, with the lower branches 5 or 6 inches long, and whorled, the upper ones, fewer and gradually shorter, becoming widely spreading, subdivided and flower-bearing to below the middle. The spikelets on the short branchlets are in pairs at each joint and in threes at the extremity. Of the pairs, one is sessile and perfect, the other is stalked and male only. Of those at the extremity, one is sessile and perfect, and two stalked and male only. The spikelets are about two lines long, ovate-lanceolate. The outer glumes of the fertile spikelets are acute, coriaceous, smooth, and shining, or with a few sparse hairs; the veins, (5 to 9) are obscure externally, but internally are plain and sometimes beautifully cross-veined. Within these thick outer glumes are two thin delicate leaflets, by some called palets, by others considered to be inner glumes, the shorter of which occasionally bears a twisted awn or beard half an inch long. The male spikelets are on stems or pedicels one line long. They are as long as the perfect flowers, but the outer glumes are much thinner, and they contain only three stamens. The flowers and seeds are similar to those of broom-corn, which belongs to the same genus.

This grass has been often called Guinea grass, but that name properly belongs to a quite different plant, *Panicum jumentorum*, of which see an account elsewhere. The underground root-stocks are sometimes half an inch thick, very succulent, and are eagerly sought for and eaten by hogs. The grass spreads and is readily propagated from these root-stocks, every joint being capable of developing a new shoot. Mr. N. B. Moore, of Augusta, Ga., has cultivated this grass for over forty years, and prefers it to all others. He says it is perennial, as nutritious as any other, when once set is difficult to eradicate, will grow on ordinary land, and yields abundantly.

My meadow consists of 100 acres of alluvial land; the grass should be cut when from 2 to 4 feet high; on such land as mine it will afford three or four cuttings if the season is propitious.

Many farmers and planters especially object to this grass because the difficulty of eradicating it. But Mr. Hubert Post says it is not hard to get rid of as many suppose. He says that one of his neighbo in 1878, broke up some 15 acres, which he has since successfully plant in cotton with no trouble from the grass. He also says that in t Johnson grass a kind Providence has given the South a mine of weal which could easily be made a foundation for wealth and prosperity su as the South has never seen. The history of the grass in this count is said to be as follows:

Governor Means, of South Carolina, obtained some of the seed fr Turkey as early as 1835. He planted it on his plantation, where it stilled called Means grass. In 1840 or 1845 William Johnson, of Alaba obtained some of the seed and sowed it upon his farm, whence it deriv the name of Johnson grass. It is said to have been introduced i California from Australia, and has there been cultivated under the na of evergreen millet. It has been tried in Kansas with very promisi results. A farmer there obtained some seed from his brother in C fornia, who had cultivated it successfully on a very dry soil on an upla farm. This farmer finds it to be in Kansas perfectly hardy, rapid growth, affording three cuttings in one season, and producing a hea growth of after-math for fall grazing. Horses and cattle are fond o both in its dry and green condition. Probably no grass gives bet promise for the dry arid lands of the West. In Utah it has been cul vated under the name of *Arabian millet grass.* (Plate 29.)

SORGHUM VULGARE. (Sorghum sugar cane, Broom corn, Chin sugar cane, Guinea corn, Doura corn, Indian millet, Chocol corn, Pampas rice, African millet, &c.)

The above-named grasses are generally believed to be all varieties *Sorghum vulgare.* Most of them are well known and cultivated for v ious purposes other than for hay or forage. The Doura corn has be extensively cultivated in some of the arid western counties of Kans where the grain is used for feed for hogs and cattle and also as hum food. The seeds of the other varieties are probably also valuable f feed for stock.

The sugar corn has been extensively cultivated at the North and We and has lately received an extraordinary impulse from the developme of successful methods of manufacturing sugar from its juice. It is al frequently sown thickly for a forage crop, and in good seasons and w proper cultivation furnishes a very heavy yield.

The botanical character may be briefly given as follows: Flowers an ample terminal panicle, loose and spreading, or close and compa erect or nodding. The flowers are on the small branches near their e tremities. If examined while young it will be observed that there a two kinds of flowers, one perfect and finally producing seeds, the oth containing only stamens or empty. The male or sterile flowers are

ort stalks, one or two at the base of each perfect flower, which is ses- e or without a stalk. At or near maturity the sterile flowers drop , leaving still remaining the short stem or stems on which they were rne. The perfect spikelet has two outer glumes, which are tough and thery, and two thin transparent inner ones, one of which is two- ed at the apex, and between the lobes extended into a short, rigid, nt and twisted awn or beard. Stamens, three; stigmas, plumose. The rile spikelets are narrower, the outer glumes without the leathery text- e, nerved longitudinally, the two inner ones thin and delicate, desti- te of the awn and containing three stamens or empty.

ALARIS.

This genus is defined as having spikelets with one perfect flower and e or two rudimentary flowers, or mere sterile pedicels, within the ter glumes and below the proper flower.

The outer glumes are compressed and boat-shaped, acute, strongly eled, becoming coriaceous or cartilaginous. The inner or true flower nsists of two thin glumes, sometimes called palets, inclosing the stae- ns and pistils. No proper palet present.

ALARIS ARUNDINACEA. (Reed canary grass.)

A perennial, grass with strong creeping rhizomas, growing from 2 to eet high, usually in low or wet ground. It ranges from New England d New York westward to Oregon, and northward to Canada, also in e mountainous parts of Pennsylvania and Virginia. It is common, o, in the north of Europe. The culm is stout, smooth, and leafy; the ves are mostly from 6 to 10 inches long, and about half an inch wide, e upper ones shorter. The ligule is about two lines long, rounded or tuse. The panicle is from 2 to 4 inches long, narrow and spike-like; e branches short and crowded above, rather distant below, slightly reading when in flower. The spikelets are three lines long; the outer mes nearly equal, nearly smooth, boat-shaped, oblong-lanceolate, nte, three to five nerved, the keel scabrous and slightly thickened ar the apex. The flowering glumes are one-third shorter, ovate, ick, somewhat hairy externally. The two sterile pedicels are about e-third as long as the flowering glumes and feathered.

The stout stems bear five or six leaves, which are 6 to 8 inches long, d a quarter to a half inch wide, smoothish except on the edge, striate d pointed. The ligule is conspicuous, thin, and rounded. This grass said to be extensively used for fodder in Sweden, and is liked by ttle. Mr. J. S. Gould says of it:

> In the province of Scania it is mown twice a year. The peasantry there use it as a atch for their cottages and hay stacks and find it is more durable than straw. It very certain that cattle in our country do not relish it either as pasture or hay, and y will not touch it as long as they can get anything better. When cut very young, y when about 1 foot high, and used for soiling, cattle eat it better than any her way.

The well-known ribbon grass of the garden is a variety of this grass, and will, it is said, easily revert to the normal type. In mountainous regions it may be worth trial for meadows. (Plate 30.)

PHALARIS INTERMEDIA. (Southern reed Canary grass, Gilbert's Relief grass, Stewart's Canary grass, California Timothy grass.)

This species resembles the foreign Canary grass (*Phalaris Canariensis*), which produces the seed commonly sold as food for Canary birds. It is, however, a taller and more robust species, growing 2 to 3 feet high, with a stout, erect culm and broad linear leaves, which are from 4 to 10 inches long. The spike is oblong and compact, 1 or 2 inches long. There is a variety called var. *angustata*, in which the spike is 3 or 4 inches long. The spikelets are much like those of the preceding species (*P. arundinacea*), having one perfect flower and two abortive ones. The outer glumes in *P. intermedia* are lanceolate and nearly alike and have a narrow wing extending down the keel. The glumes of the fertile flower are nearly like those of *P. arundinacea* already described.

This species grows in South Carolina and the Gulf States, extending to Texas, then stretching across to the Pacific coast and occurring through California and Oregon. It has frequently been sent to the Department from the Southern States as a valuable winter grass.

Mr. Thomas W. Beaty, of Conway, S. C., writes as follows:

> The grass I send you was planted last September, and the specimens were cut on the 9th of March (following). You will notice that it is heading out and is just now in a right condition for mowing. It is wholly a winter grass, dying down in the latter part of April and first of May, and it seems to me should be a great thing for the South if properly introduced and cultivated, or rather the ground properly prepared and the seed sown at the right time. It would afford the best of green pasturage for sheep and cattle all winter. It is what we call Gilbert's relief grass.

Many years ago Dr. Lincecum, of Texas, experimented with this grass and recommended it very highly. In California it is called California timothy, and is said to have little or no agricultural value. It is an annual or biennial. Professor Phares says:

> The variety *angustata* is much larger and more valuable. It grows 2 to 3 feet high, and in swamps 5 feet, with many leaves 4 to 10 inches long, the spike somewhat resembling the head of timothy; stock like it well, especially as hay. Mr. D. Stewart, of Louisiana, having tested other grasses, prefers this for quantity and quality for winter and spring grazing, and for soiling for milk cows. There is much testimony from many parts of the South of the same import, and this grass is doubtless worthy of extended, careful testing.

(Plate 31.)

ANTHOXANTHUM ODORATUM. (Sweet vernal grass.)

A perennial grass, native of Europe, much employed as a part of mixed lawn grasses, and also frequently found in meadows. It grows thinly on the ground, with slender culms, seldom more than 1 foot to 18 inches in height, and scanty in foliage. The panicle is 2 to 3 inches long, narrow and close, but expands considerably during flowering time.

The spikelets are clustered, three to four lines long, and with one perfect flower. There are two pairs of empty glumes; the outer pair is unequal; the lower are about half as long as the second; both are acute and keeled. Within these glumes is a second pair, about half as long as the first, thin, two-lobed, hairy, and with an awn or bristle on the back longer than the longest outer glume. These may be considered as abortive or defective flowers. Between these inner glumes is the fertile flower, consisting of another pair of glumes, inclosing the floral organs. These glumes are commonly called palets; they are less than a line long, thin and transparent, the lower one broad and three-nerved, the upper narrow and one-nerved. There are two stamens and two styles.

This grass is very fragrant and gives a pleasant odor to hay which contains it. Mr. J. Stanton Gould says:

> It is nowhere considered a very valuable variety for hay, as the culms are wide apart, very thin, and bear but few leaves; hence it gives a light crop of hay.

(Plate 32.)

HIEROCHLOA BOREALIS. (Vanilla or Seneca grass. Holy grass.)

This is a perennial grass of northern latitudes, growing in moist meadows near the coast, also in low marshy ground in some parts of Illinois and other States bordering the Great Lakes, and in the mountains of Colorado and northward. The name *Hierochloa* means sacred grass, so called because it, with other sweet-scented grasses, was strewed before the church doors in the north of Europe. The culms grow from 1 to 2 feet high, with short lanceolate leaves, and an open pyramidal panicle from 2 to 5 inches long. The spikelets are three-flowered, the third or terminal one perfect, but with only two stamens; the two lower flowers of the spikelet are male only, each with three stamens. The two outer glumes are thin and scarious, acutely keeled; the glumes of the male flowers are thicker, slightly pubescent, and fringed on the margins with soft brownish hairs, sometimes with a very short awn from the apex, and inclosing a narrow, bifid, two-keeled palet; the upper or perfect flower has a one-nerved glume in place of the usual palet. This grass is very sweet-scented and is often used to perfume drawers, &c. It grows commonly in the northern parts of Europe, as Norway, Sweden, and Russia. In our country it does not appear to be adapted to general cultivation. There are two other species native to this country. (Plate 33.)

(1.) *Hierochloa alpina* growing on mountains at high altitudes, and (2) *Hierochloa macrophylla*, a largeleaved, robust species, growing in California, whose value for agricultural purposes is undetermined.

ALOPECURUS PRATENSIS. (Meadow Fox tail.)

This is a perennial grass, native of Europe, but has been introduced and is frequently found in meadows in the Eastern States. It has considerable resemblance to timothy, but will be readily distinguished by

an examination. It ordinarily grows about 2 feet high but frequently in good soil reaches 3 feet or more. The culms are erect, with four or five leaves at pretty uniform distances. The sheaths are long and rather loose, particularly on the upper one. The blade of the leaf is 3 or 4 inches long, about one-quarter inch wide, at the base and tapering gradually to a point. The panicle terminates the stalk and is a cylindrical spike 2 or 3 inches long, dense, soft, and with the awns of the flowers conspicuously projecting. The spikelets are single-flowered, between two and three lines long. The outer glumes are strongly compressed, boat-shaped, keeled, nearly equal, sometimes slightly united together at the base, and have a line of soft, short hairs on the keels. These glumes closely inclose the flower, which is of nearly the same length, and consists of a flowering glume (formerly called the lower palet) and the floral organs, but without any true palet. This flowering glume is folded upon itself and incloses the stamens and styles. It gives rise on its back near the base to a fine awn, which extends two or three lines beyond the glumes.

Mr. J. S. Gould says:

It flourishes in May, nearly four weeks in advance of timothy, and is one of the earliest grasses to start in the spring. Pastures well covered with this grass will afford a full bite at least one week earlier than those which do not have it. It does not flourish in dry soils, but loves moist lands; no grass bears a hot sun better, and it is not injured by frequent mowings, on which account, as well as for its early verdure, it is valuable for lawns.

There is a variety of this grass called *A. alpestris*, growing in the Rocky Mountains, which may possibly be utilized there.

Mr. Charles L. Flint says:

It is a valuable pasture grass on account of its early and rapid growth, and of its being greatly relished by stock of all kinds. The stems and leaves are too few and light to make it so desirable as a field crop. It thrives best on a rich, moist, strong soil, and shoots up its flowering stalks so much earlier than timothy, that it need not be mistaken for that grass, though at first sight it considerably resembles it. It is superior to timothy as a permanent pasture grass, enduring the cropping of sheep and cattle better, and sending up a far more luxuriant aftermath. It is justly regarded, therefore, as one of the most valuable of the native pasture grasses of England forming there a very considerable portion of the sward and enduring a great amount of forcing and irrigation. Though forming a close and permanent sod when fully set, it does not acquire its full perfection and hold of the soil until three or four years after being sown.

(Plate 34.)

ALOPECURUS GENICULATUS. (Water Fox tail.)

This species, especially the variety *aristulatus*, is native to this country. It is commonly found on the muddy banks of streams and lakes, and sometimes is found in wet meadows and ditches. It seldom grows more than a foot in height; the stem is usually bent at the lower joints, and the sheaths of the leaves are more or less swollen, especially the upper one. It is of no value for cultivation, being only useful for the amount of grass it may contribute to the wild forage where it grows.

ALOPECURUS ALPINUS.

A species resembling the *Alopecurus pratensis* grows in alpine meadows in the Rocky Mountains.

ARISTIDA.

This is a genus of grasses of which many species are found in the United States, Mexico, and South America. They are principally annual grasses and are of little value, unworthy of cultivation, but in some regions, particularly the arid Western plains, they furnish a portion of the wild forage.

ARISTIDA PURPURASCENS. (Beard grass, Three-awned grass.)

This species grows in many of the States east of the Mississippi River, usually in poor, sandy, or clay soil, in thin woods or barren fields. It grows usually about 2 feet high, with a slender, smooth culm, narrow leaves, which are inclined to be involute when dry, and with a narrow, loose, spike-like panicle a foot or more long, which usually gracefully droops or bends. The branches are short, appressed, mostly single at the joints of the axis, and each having seldom more than two or three spikelets. The spikelets are single-flowered, the outer glumes are narrowly linear, four or five lines long, the lower one slightly the longer, both usually sharply pointed. These glumes inclose the flower, which consists of a slender, almost cylindrical flowering glume about three lines long, having a short-pointed, hairy base, and a long, three-bearded apex. This glume enrolls the narrow, thin palet and the floral organs. The awns or beards are widely spreading, the middle one about an inch long, the two lateral ones somewhat shorter. (Plate 35.)

ARISTIDA PURPUREA. (Western Beard grass. Purple Three-awned grass.)

This species prevails extensively west of the Mississippi River, from British America to Mexico, and is abundant on the plains of Kansas, New Mexico, and Texas. It grows usually 1 to 1½ feet high, with slender culms, branching at the base, and with short, involute leaves. It is an exceedingly variable species, or there are several distinct varieties. The panicle is 6 to 8 inches long, rather narrow, erect, or flexuous. The spikelets are much like those of the preceding species, but usually larger and with longer awns or beards. In some varieties these awns are 2 or 3 inches long, widely diverging, and purplish colored, the whole panicle having a graceful and feathery appearance.

Like the other species, this is an inferior grass, but furnishes a considerable amount of wild forage. (Plate 36.)

ARISTIDA BROMOIDES.

A small, apparently annual, grass, growing in New Mexico, Arizona, and Southern California. It grows in tufts, the culms from 6 to 12 inches high, slender, erect, and generally unbranched. The spikelets are seven to eight lines long, including the awn. (Plate 37.)

STIPA. (Feather grass, Beard grass.)

A genus mostly of coarse, rigid grasses, chiefly Western, in structure and habit resembling the preceding genus. It differs in having the spikelets usually longer and the flowering glume having a single undivided awn or beard.

STIPA VIRIDULA. (Bunch grass.)

A perennial grass, culms 2 to 4 feet high, leafy; the radical leaves 12 to 18 inches long, those of the stem 4 to 10 inches long, one to two lines wide, involute, and bristle-like at the point; sheaths long, smooth, the uppermost inclosing the base of the panicle; panicle very variable in size, from 6 inches to a foot or more, narrow and loose, variable in thickness, the branches mostly in twos or threes, erect and appressed, much subdivided; spikelets, one-flowered on short pedicels; outer glumes four to six lines long, bristle-pointed, nearly equal, lanceolate, three to five nerved, thin; flowering glume three to four lines long, cylindrical, covered with short, scattered hairs, which are longer at the minutely two-toothed apex, which is terminated by a slender awn 1 to 1½ inches long, once or twice bent, twisted and sparsely pubescent below, scabrous above. The palet is narrow and shorter than its glume, by which the floral organs and it are involved. Widely diffused over the Rocky Mountain region, extending to California, Oregon, and British America, furnishing a considerable part of the wild forage of the region. (Plate 38.)

STIPA SETIGERA. (Bear-grass, Bunch grass.)

A perennial grass, growing in bunches on dry hills and plains from Oregon to Southern California and eastward to Arizona and Texas. The culms are 2 to 3 feet high, erect, somewhat pubescent at the joints, with about three leaves. The sheaths are long and somewhat scabrous, the upper one loose and inclosing the base of the panicle; the blade flat, two or three lines wide, 4 to 6 inches long, roughish and long-pointed; the upper one nearly as long as the panicle, which is about 6 inches long, loose, the rays mostly in pairs, rather distant, slender, bearing near the extremity the few spikelets on short pedicels. Spikelets one-flowered, the outer glumes one-half to two-thirds of an inch long, the upper one rather shorter, narrow, acute, purplish and three-nerved. The flowering glume is nearly cylyndrical, four to five lines long, sparingly hairy above, with a short, stiff point at the base called a callus, and a hardened ring at the apex, to which is attached the slender, twisted awn, 2 to 3 inches long, the lower part of which is softly pubescent. Professor Brewer says this is the most common and most valuable "bunch grass" of the hills of California. (Plate 39.)

STIPA EMINENS. (Feather grass, Beard grass.)

A very common species in California on dry hills, growing in rather small tufts with numerous short and narrow root-leaves. It is a per-

ennial, growing usually 2 to 3 feet high, with rather slender culms, and slightly hairy joints. The leaves are very narrow and convolute, rather rough and rigid, the lower ones about half the length of the culm. The panicle is rather narrow, but open and loose, usually about 6 inches long, at first sheathed by the upper leaf, but becoming exerted; the branches are slender, in pairs, and flower-bearing above the middle. The spikelets, as in the preceding, are single-flowered, the outer glumes about half an inch long, very narrow, three-nerved, and long, fine-pointed. The flowering glume is very similar to that of the preceding, rather shorter and smaller, with a ring of very short hairs at the apex, and with an awn about an inch long, which readily separates from its glume. (Plate 40.)

Stipa spartea and *Stipe comata* are two species, also called bunch grasses, which prevail from British America southward, on the plains and in the mountain region, very similar in general appearance to the preceding, but usually with longer awns, sometimes 6 inches long.

Mr. Robert Miller Christy, writes about these grasses in Manitoba, where they are common, that there is much complaint concerning them among stockmen on account of the injury they do to sheep by the penetration into their wool, and even into the flesh, of the sharp-pointed and barbed awns of the seeds.

Stipa avenacea is the only species prevailing in the Eastern and Southern States. It is more slender than those previously mentioned, and grows sparsely in open woods or on rocky hills. It is of no agricultural importance.

ERIOCOMA CUSPIDATA. (Bunch grass.)

This grass has a wide distribution, not only on the Sierras of California, but northward to British America, and eastward through all the interior region of Utah, Nevada, New Mexico, Texas, Colorado, and Nebraska to the Missouri River. It is a perennial, growing in dense tufts, whence its common name of bunch grass. The culms are 1 to 2 feet high, with about three narrow, convolute leaves, the upper one having a long, inflated sheath which incloses the base of the panicle. The radical leaves are narrow, rigid, and as long as or longer than the culm. The panicle is about 6 inches long, very loose, spreading, and flexuous. The branches are in pairs, slender, rather distant, and are subdivided mostly in pairs. The spikelets are at the ends of the capillary branches, each one-flowered. The outer glumes are three to four lines long, inflated and widened below, gradually drawn to a sharp-pointed apex, thin and colorless except the three or five green nerves, and slightly hairy. The glumes inclose an ovate flower, which is covered externally with a profusion of white, silky hairs, and tipped with a short awn, which falls off at maturity. This apparent flower is the flowering glume of a hard, coriaceous texture, and incloses a similar hard, but not hairy, and smaller palet. (Plate 41.)

MILIUM EFFUSUM. (Wild millet.)

A perennial, rather slender, grass, 4 or 5 feet high, growing in damp woods in the northern portions of the United States and in Canada. It is also found in Northern Europe and in Russian Asia. There are four to five joints to the culm, each provided with a leaf which is broad and flat, 6 to 12 inches long, and half an inch wide, smooth above and roughish below. The sheaths are long and smooth. The panicle is loose and spreading, 6 to 10 inches long, the slender branches mostly in fives, of unequal length, the longer ones 2 to 3 inches, and flowering near the extremities. The whorls are from 1 to 2 inches apart. The spikelets are single-flowered, consisting of a pair of thin, concave, smoothish, empty glumes, one to one and one-half lines long, rather exceeding the flowering glume, which is thick and hard, very smooth and shining, and inclosing the palet which is of similar texture. The flowers are in structure similar to those of *Panicum*, to which this grass is closely related.

Hon. J. S. Gould, in the Report of the New York State Agricultural Society, says respecting this grass:

Mountain meadows and borders of streams and cold woods. It thrives when transplanted to open and exposed situations. It is one of the most beautiful of the grasses; the panicle is often a foot long, and the branches are so exceedingly delicate that the small glossy spikelets seem to be suspended in the air. Birds are very fond of the seed. Mr. Colman says that he has raised 3 tons to the acre of as good nutritious hay as could be grown from it, when sown in May. The plants multiply by the roots as well as by the seed, sending out horizontal shoots of considerable length, which root at the joint as they extend.

(Plate 42.)

MUHLENBERGIA. (Drop seed grass.)

There are many species of this genus, mostly perennials. It is characterized as having small, one-flowered spikelets, generally in open panicles. The outer glumes are variable in size in different species, in some minute, in others nearly as large as the flowering glume, sometimes bristle-pointed, sometimes very blunt, and sometimes toothed at the apex. The flowering glume is longer than the outer glumes, with a short more or less hairy callus at the base, three to five nerved, thinnish or rigid mucronate pointed, or commonly with a long capillary awn from the apex; the palet as long as the flowering awn and of similar texture.

MUHLENBERGIA DIFFUSA. (Nimble will, Drop seed, Wire grass.)

This species is perennial, low with much-branched, decumbent stems and slender panicles of flowers. The outer glumes are very minute, so small as to be scarcely visible to the naked eye, transparent and obtuse; the flowering glume little more than a line long, tipped with a fine awn or beard once or twice its own length.

Professor Killebrew, of Tennessee, says:

It is hardly more than necessary to mention this grass, which forms in many sections the bulk of the pastures of the woods. It does not grow in fields, but in woods, where, after rains have set in, it carpets the earth with living green. Various opinions are entertained as to its nutritive qualities. Some farmers assert that their stock are fond of it, and that on sufficient range cattle, horses, and sheep will go into the winter sleek and fat from this vigorous grass. Others regard it as well nigh worthless.

According to the analysis of the chemist of this Department it has a very good amount of nutritive properties. It is considered by some that it is a good butter-producer and gives a good flavor to butter. In cultivation, no doubt, its place can be supplied with much more productive grasses. (Plate 43.)

MUHLENBERGIA MEXICANA. (Wood grass.)

A perennial grass of decumbent habit, 2 to 3 feet high, very much branched, from scaly creeping root-stocks. The culm has numerous short joints, which frequently are bent and rooting near the base, and sending out many long, slender, leafy lateral branches. From these branches and from the apex of the culm arise the flowering panicles, which are sometimes partially included in the leaf sheaths. The leaves are 3 to 4 inches long and two to three lines wide, gradually pointed. The panicles are narrow, usually 2 to 3 inches long, and composed of five to ten spike like branches, closely approximated or distant and interrupted below. The spikelets are single-flowered; the outer glumes are abruptly sharp-pointed and nearly as long as the flowering glume, which is narrow, strongly three-nerved, and acute, with usually a few soft hairs at the base and on the nerves. The palet is of equal length with its glume, which is also acute, but not bristle-pointed.

This grass is frequently found in moist woods and low meadows or in prairie bogs. It probably would not endure upland culture, but in its native situations it fills an important part among indigenous grasses. (Plate 44.)

MUHLENBERGIA SYLVATICA. (Wood grass.)

This species in habit and appearance is very much like that of the preceding. The panicle is looser, the spikelets not so densely clustered, and the flowering glume bears an awn two or three times as long as itself. The outer glumes are generally bristle-pointed, but they vary much in this respect, in some forms being only acute. It inhabits drier situations than the *M. Mexicana*, being found in dry, open, or rocky woods and fence-corners. In agricultural value it corresponds with that species. (Plate 45.)

MUHLENBERGIA GLOMERATA. (Spiked Muhlenbergia.)

This grass grows in wet, swampy grounds, chiefly in the northern and western portions of the United States. It is found in Colorado,

Utah, Nevada, New Mexico, and Texas. It grows to the height of 2 or 3 feet, stiffly erect, and generally unbranched. The culm is hard, somewhat compressed, and very leafy. The panicle is narrow, 2 to 4 inches long, composed of numerous close clusters of flowers, becoming looser below, forming an interrupted glomerate spike. The spikelets are closely sessile in the clusters. The outer glumes are linear-lanceolate, gradually tapering into an awn or bristle of equal length. The flowering glume is one-third to one-half shorter than the outer glumes and very acute. The root-stock is hard and knotty and furnished with numerous short, firm shoots or stolons. In the Eastern States it is utilized as one of the native products of wet meadows in the making of what is called wild hay. Specimens have been sent from Colorado and Kansas and recommended as an excellent grass for hay. (Plate 46.)

MUHLENBERGIA COMATA. (Wooly-seeded Muhlenbergia.)

This species is closely related to the preceding. It grows throughout the Rocky Mountain region in Colorado, Utah, Wyoming, Idaho, Nevada, and California, usually on the sandy or alluvial banks of streams. It grows in tufts from firm, creeping root-stocks. There is reason to think it may be a valuable grass for arid regions. The culms are erect, simple, 2 to 3 feet high, leafy below, the leaves 3 to 6 inches long and roughish, the upper one at first inclosing the base of the panicle, the joint slightly pubescent. The panicle is 2 to 4 inches long, narrow, and close, sometimes interrupted below, generally of a purplish lead color and of soft texture. The spikelets are nearly sessile, the outer glumes very narrow, acute, nearly equal, one-nerved, one and one-half to two lines long. The flowering glume is rather shorter, and surrounded at the base by a copious tuft of long, silky hairs. It is also terminated by a slender awn three or four times as long as the flower. The palet is slightly shorter than its glume and acute. (Plate 47.)

MUHLENBERGIA GRACILIS. (Graceful Muhlenbergia.)

A perennial grass growing in tufts or loose patches from a creeping root-stock, much branched at the base. The culms are erect, much branched, slender, and wiry, 1 to 1½ feet high; the leaves mostly radical, involute, and bristle-like, 2 to 6 inches long, scabrous on the edges. The panicle is erect or somewhat nodding, 3 to 6 inches long, narrow, very loose, the branches erect, rather distant, and mostly single. The spikelets are on short pedicels; the outer glumes unequal, the lower one ending abruptly in a slender point, the upper one three-nerved and three-toothed, the teeth usually prolonged into short awns; the flowering glume is somewhat cylindrical, taper-pointed, and with a straight awn about half an inch long; palet as long as its glume without the awn.

This species, of which there are several varieties, inhabits the arid regions of Colorado, New Mexico, and Arizona. It is too small to be of much economic importance. (Plate 48.)

PHELUM PRATENSE. (Timothy, Herd's grass.)

This is one of the commonest and best-known grasses. For a hay crop it is, perhaps, the most valuable, especially in the Northern States. The heighth of the grass depends on the soil and cultivation. In poor ground it may be reduced to 1 foot, while in good soil and with good culture it readily attains 3 feet, and occasionally has been found twice that height. It is a perennial grass with fibrous roots. The base of the culm is sometimes thickened and inclined to be bulbous. The culm is erect and firm, with four or five leaves, which are erect and usually from 4 to 6 inches long. The flower spike varies from 2 to 6 inches in length, is cylindrical and very densely flowered. The spikelets are sessile, single-flowered, and cylindrical or oblong in outline. The outer glumes are rather wedge-form, with a mucronate point or short bristle. The main nerve on the back is fringed with a few short hairs. The flowering glume is shorter than the outer ones and thinner, five-nerved, and toothed at the apex. The palet is thinner in texture and much narrower.

This grass, as known in cultivation, is supposed to have been introduced from Europe, but it is undoubtedly indigenous in the mountain regions of New England, New York, and the Rocky Mountains. It is said that about the year 1711 a Mr. Herd found this grass in a swamp in New Hampshire and cultivated it. From him it took the name of Herd's grass. About the year 1720 it was brought to Maryland by Timothy Hanson and received the name of Timothy grass. It is now the favorite and prevailing meadow grass over a large part of the country.

Mr. Charles L. Flint says:

As a crop to cut for hay it is probably unsurpassed by any other grass now cultivated. Though somewhat coarse and hard, especially if allowed to ripen its seed, yet if cut in the blossom or directly after, it is greatly relished by all kinds of stock and especially so by horses, while it possesses a large percentage of nutritive matter in comparison with other agricultural grasses. It is often sown with clover, but the best practical farmers are beginning to discontinue this custom on account of the different times of blossoming of the two crops. It grows very readily and yields very large crops on favorable soils. It yields a large quantity of seed to the acre, varying from 10 to 30 bushels on rich soils.

(Plate 49.)

SPOROBOLUS INDICUS. (Smut grass.)

This grass is a native of India, but has spread over most tropical and warm climates. It occurs more or less abundantly in all the Southern States, and is called smut grass, from the fact that after flowering the heads become affected with a black smut. It grows in tufts or loose patches, is erect, from 1½ to 3 feet high, with an abundance of long, flat, fine pointed leaves near the base, and a narrow, terminal panicle frequently a foot in length, composed of short, erect, sessile branches, which are very closely flowered. The spikelets are narrow, less than a

line long; the outer glumes unequal, thin, and nerveless, the upper one about half as long as the flower, the lower one, still shorter, obtuse or truncate; the flowering glume and palet are of nearly equal length, membranaceous, lead-colored, smooth; the glume acute; the palet obtuse.

Professor Phares says:

> It grows abundantly and luxuriously on many uncultivated fields and commons, and furnishes grazing from April till frost. It thrives under much grazing and many mowings, and grows promptly after each if the soil be moist enough. Cattle and horses are foud of it if frequently cut or grazed down, but if allowed to remain untouched long they will not eat it unless very hungry, as it becomes tough and unpalatable and probably difficult to digest.

Professor Killebrew also speaks favorably of it and recommends it for trial under cultivation. (Plate 50.)

SPOROBOLUS CRYPTANDRUS.

This species grows chiefly in sandy soil. It is stouter than the preceding, growing in loose tufts; the culms frequently bent at the lower joints, then rising erect to the height of 2 or 3 feet. The leaves are mostly near the base, where the joints of the culms are short; here the sheaths are short and the blades of the leaves 5 to 6 inches long; the upper sheaths become longer and the blades shorter; the leaves are flat, but become involute in dry weather. The top of the sheath is fringed with fine soft hairs. The long and narrow panicle is for a long time completely inclosed in the very long sheath of the upper leaf, but finally emerges except the base and becomes more or less spreading. The full panicle is from 6 to 12 inches long, the branches mostly alternate or scattered, the lower ones about 1 inch apart and 2 inches long, the upper ones much closer and shorter, all flowering nearly to their bases with the spikelets short stalked and appressed.

This species is very common in sandy fields in the Northern and Southern States, as well as over all the dry plains west of the Mississippi River, extending from British America to Mexico, where it furnishes a portion of the wild pasturage. It deserves observation and experiment as to its value. (Plate 51.)

SPOROBOLUS HETEROLEPIS.

This species grows in dense, firmly-rooted tufts, principally west of the Mississippi River, from British America to Texas. The culms are 1½ to 3 feet high, erect, smooth. The radical leaves are very long and narrow; those of the culm, 3 or 4, with long sheaths and blades, becoming involute when dry. The panicle is from 3 to 8 inches long, rather narrow and loose; the branches, two to three together, slender, and with few rather distant flowers. The spikelets are one-flowered, sessile or nearly sessile, on the slender branches; they are about two lines long, unequal, acutely long-pointed, the lower one a little shorter and the upper a little longer than the flower. The flowering glumes and palet

are of about equal length and texture; the seed is perfectly round, smooth and shining, thick and coriaceous.

A writer on the grasses of the Rocky Mountains and plains in the Agricultural Report for 1870 says:

This species may be identified from its long, slender leaves; growing abundantly from the base of the plant, gracefully curving and frequently resting their tips on the ground; from its tendency to grow branches or stools, and when in fruit, from its small panicle of sharp-pointed spikelets and its round seeds. These when bruised emit a strong, heavy oder, which has been compared to that of *Eragrostis megastachya* when crushed in the hands; but to most olfactories it is much less offensive, and to some not at all disagreeable. It attains to the average height of about 2½ feet in fruit, but in dry seasons large tracts almost exclusively composed of this species are without a single fruiting plant. It is sometimes cultivated for hay, in the absence of the more productive species, and makes an article of fine quality.

SPOROBOLUS AIROIDES. (Salt grass.)

Culms arising from strong perennial creeping root-stalks, 2 to 3 feet high, thickened at the base and clothed with numerous long, rigid, generally involute, long-pointed leaves, which are smooth and bearded in the throat of the sheath, panicle becoming exerted and diffuse, 6 to 12 inches long, 3 to 4 inches wide; the branches capillary, scattered, mostly single, or in whorls below, the branches subdivided above the middle and rather sparsely flowered.

The spikelets are one-flowered, purplish, on short slender pedicels. The outer glumes are unequal, thin, nerveless, or obscurely nerved, oblong, the lower half as long as the upper, the upper one rather shorter than the flowering glume, which is about one line long, oblong, obtusish or minutely dentate at the apex; palet about equal to its glume; bidentate.

A common grass throughout the arid regions of the West, sometimes called salt grass, and affording considerable pasturage in some places. (Plate 52.)

AGROSTIS. (Bent grass.)

This genus has many species all characterized by having one-flowered spikelets; the outer glumes acute, one-nerved, and awnless, nearly equal, or the lower rather longer, and longer than the flowering glume, which is very thin, three to five nerved, awnless or awned on the back; palet shorter than the flowering glume, frequently reduced to a small scale or absent.

AGROSTIS VULGARIS. (Red top, Fine top, Herd's grass of Pennsylvania Borden's grass, Bent grass.)

A perennial grass, growing 2 or 3 feet high from creeping root-stocks, which interlace so as to make a very firm sod; the culms are upright, or sometimes decumbent at the base, smooth, round, rather slender, and clothed with four or five leaves, which are flat, narrow, and roughish, from 3 to 6 inches long, with smooth sheaths, and generally truncate

ligules. The panicle is oblong in outline, 4 to 6 inches long, open, composed of eight or ten joints or whorls, the lower branches mostly in fives, slender, unequal, the longer ones much subdivided. The spikelets are about a line long, varying from greenish to purple. The outer glumes are lanceolate and pointed, nearly alike in size, smooth, except the more or less roughened keel. The flowering glume is but little shorter than the outer ones, thin and delicate, and occasionally with a minute awn on the keel. The palet is narrow, and from half to three fourths as long as its glume, and inclosing the floral organs. There are several varieties of this grass, which are by some botanists considered a distinct species.

Agrostis alba, the *Fiorin* grass of Ireland, and *Agrostis stolonifera* are usually considered synonymous, and are distinguished from *A. vulgaris* by having a closer, more verticillated panicle, and with longer and more acute ligules.

Mr. J. G. Gould says of *Agrostis vulgaris*:

This is a favorite grass in wet, swampy meadows, where its interlacing, thick roots consolidate the sward, making a firm matting which prevents the feet of cattle from poaching. It is generally considered a valuable grass in this country, though by no means the best one. Cattle eat hay made from it with a relish, especially when mixed with other grasses. As a pasture grass it is much valued by dairymen, and in their opinion the butter would suffer much by its removal.

Professor Phares, of Louisiana, says respecting this grass:

It grows well on hill tops and sides, in ditches, gullies, and marshes, but delights in moist bottom land. It is not injured by overflows, though somewhat prolonged. It furnishes considerable grazing during warm spells in winter, and in spring and summer an abundant supply of nutrition. Cut before maturing seed, it makes good hay and a large quantity. It seems to grow taller in the Southern States than it does farther north, and to make more and better hay and grazing.

Mr. Flint says:

It is a good permanent grass, standing our climate as well as any other, and consequently well suited to our pastures, in which it should be fed close; for if allowed to grow up to seed the cattle refuse it; and this seems to show that it is not so much relished by stock as some of the other pasture grasses.

(Plate 53.)

AGROSTIS EXARATA. (Northern Red top, Mountain Red top.)

This is chiefly a northern species, being found in Wisconsin and westward to the Rocky Mountains, also in British America, and California to Alaska. It is very variable in appearance, and presents several varieties. It is generally more slender in growth than the common red top. The panicle is usually longer, narrower, and looser. In all the forms the palet is wanting or is very minute. The form chiefly growing on the Pacific slope from California to Alaska is often more robust than the *A. vulgaris*, growing 2 to 3 feet high, with a stout, firm culm, clothed with three or four broadish leaves, 4 to 6 inches long. The panicle is 4 to 6 inches long, pale green, rather loose, but with erect branches.

The outer glumes are of about equal length, accuminate, rough on the keel. The flowering glume is one-third shorter than the outer ones, rather acute, four-nerved, the nerves extended into short points or teeth, and rarely with a very short awn on the back. The palet if present is very minute, scarcely as long as the ovary.

There is reason to believe that this grass can be made to supply the same valuable place on the Pacific coast that the *A. vulgaris* does at the East, but it requires investigation and experiment. (Plates 54 and 54*a*.)

AGROSTIS MICROPHYLLA.

This is a species belonging to the western coast and the adjacent mountains. It is apparently an annual or biennial, frequently with several culms springing from one root. The radical leaves are few and short. The culms are erect, stiff, 1½ to 3 feet high, with four or five rough and rather rigid leaves 3 to 6 inches long, two or three lines wide, and gradually pointed. The sheaths are long and roughish. The panicle is 3 to 5 inches long, erect, spikelike, narrow, and densely flowered, sometimes interrupted below. The spikelets are densely crowded on the short, almost sessile, branches. The outer glumes are slightly unequal, rather more than a line in length; awn pointed, narrowly lanceolate, scabrous or hispid on the keel. The flowering glume is about half as long as the outer glumes, thin, acute, two-toothed at the summit, and on the back, about one-third below the apex, furnished with a slender awn three times its own length, which is readily seen projecting beyond the outer glumes. There is no proper palet or only a microscopic one. This grass deserves the attention of those who live in its habitat. It may prove a useful species. (Plate 55.)

AGROSTIS CANINA. (Dog's Bent Grass, Mountain Red top.)

A grass usually of low size, 6 to 12 inches high, with slender culms, and a light, flexible, expanded panicle, growing in elevated regions or in high latitudes, and with a perplexing variety of forms. The radical leaves are numerous, but short and narrow. The culm has two or three fine short leaves, 1 or 2 inches long, the ligule acute, short but conspicuous. The panicle is pyramidal in form, 3 or 4 inches long, of few capillary branches, which are in pairs, horizontal in flower, more erect and close in fruit, dividing near the extremities into a few sparsely flowered branchlets. The spikelets are on short, fine pedicels; the outer glumes nearly equal, ovate and acute, one to one-half line long; the flowering glume is about a quarter shorter than the outer ones, thin, smooth, obtuse, and bearing on the back, about the middle, a fine, straight awn about two lines long; the palet is so minute as to be hardly visible to the naked eye.

There are several varieties of this grass growing in mountainous regions throughout the United States and in Europe. It forms a close sod, and affords considerable pasturage in those regions. (Plate 56.)

POLYPOGON MONSPELIENSIS. (Beard grass.)

An annual grass frequent in California, Oregon, Arizona, Texas, and Utah, and sometimes found on the Atlantic coast. It is a native of Europe. The culms are from 6 inches to 2 feet high, rather stout, apt to be procumbent at the base, and often branching below. There are usually three or four leaves on the culm, which are broad, flat, 3 to 6 inches long, and somewhat rough; the sheaths are rather loose and striate, and the ligule long and obtuse. The panicle varies from 1 to 4 inches in length, contracted into a dense cylindrical spike, of a shining, yellowish-green color, the long awns or beards of the flowers being very conspicuous. The spikelets are one-flowered, about one line long. The outer glumes are nearly equal, one-nerved pubescent, notched at the apex, the midnerve extended into a slender awn or beard from two to four times as long as the glume. The flowering glume is about half as long as the outer ones, thin, toothed at the apex, and usually having a fine awn about one line long; the palet is smaller, thin, delicate, and without an awn. It is quite an ornamental grass, but of little agricultural value. (Plate 57.)

CINNA ARUNDINACEA. (Wood Reed grass.)

A perennial grass, with erect, simple culms from 3 to 6 feet high, with a creeping rhizoma; growing in swamps and moist, shaded woods in the northern or mountainous districts. The leaves are broadly linear-lanceolate, about 1 foot long, four to six lines wide, and with a conspicuous elongated ligule. The panicle is from 6 to 12 inches long, rather loose and open in the flower, afterwards more close. The branches are four or five together below, about 2 inches long, above in twos or threes and shorter. The spikelets are one-flowered, much flattened, rather crowded on the branches, frequently purple colored. The glumes are linear-lanceolate, roughish, acute, and strongly keeled, mostly three-nerved, firm in texture, about two lines long, the lower rather the shorter. The flower is short-stalked within the glumes; the flowering glume is as long as the outer ones, and of the same texture, rather scabrous and three-nerved, and usually with a very short awn near the apex. The palet is rather shorter than its glume, thin and membranaceous, except on the green somewhat rough nerve. This is one of the very rare cases in which the true palet has only a simple nerve, probably, Mr. Bentham says, by the consolidation of two. There is but one stamen.

This leafy-stemmed grass furnishes a large quantity of fodder, but experiments are wanting to determine its availability under cultivation. (Plate 58.)

There is another species, *Cinna pendula*, which is more slender, with a looser drooping panicle and more capillary branches, and with thinner glumes. It occurs in the same situations as the preceding, and is more common in the Rocky Mountains and Oregon.

DEYEUXIA (CALAMAGROSTIS.)

This genus is characterized by having one-flowered spikelets, with the addition at the base of the flowering glume of a small hairy appendage or pedicel, which is considered to be the rudiment of a second flower. In addition to this the flower is also generally surrounded at the base with a ring of soft hairs, and the flowering glume usually bears an awn on its back, which is generally bent and twisted. Our species have been until recently included in the genus *Calamagrostis*, which is principally a very similar European genus.

DEYEUXIA (CALAMAGROSTIS) CANADENSIS. (Blue Joint, Small Reed grass.)

A stout, erect, tall perennial grass, growing chiefly in wet, boggy ground or in low, moist meadows. Its favorite situation is in cool, elevated regions. It prevails in all the northern portions of the United States, in the Rocky Mountains, and in British America. In those districts it is one of the best and most productive of the indigenous grasses. It varies much in luxuriance of foliage and size of panicle, according to the location. The culms are from 3 to 5 feet high, stout and hollow, hence in some places it is called the small reed-grass. The leaves are a foot or more long, flat, from a quarter to nearly half an inch wide, and roughish; the stem and sheaths smooth.

The panicle is oblong in outline, open, and somewhat spreading, especially during flowering; it is from 4 to 6 or even 8 inches in length, and 2 or 3 inches in diameter, of a purplish color; the branches are mostly in fives at intervals of an inch or less. These branches vary in length from 1 to 3 inches, the long ones flowering only toward the extremity. The spikelets are short-stalked, the outer glumes about one and one-half lines long, lanceolate and acute; the silky white hairs at the base of the flowering glume, are about as long as the glume; those on the sterile pedicel also nearly as long. The flowering glume is thin and delicate, about as long as the outer glumes, and somewhat finely toothed at the apex, three to five nerved, and bearing on the back, below the middle, a delicate awn, reaching about to the point of the glume, and not much stouter than the hairs. The proper palet is thin, oblong, and about two-thirds the length of its glume.

Mr. J. S. Gould says:

> It constitutes about one-third of the natural grasses on the Beaver Dam Meadows of the Adirondacks. It is certain that cattle relish it very much, both in its green state and when made into hay, and it is equally certain that the farmers who have it on their farms believe it to be one of the best grasses of their meadows.

(Plate 59.)

DEYEUXIA SYLVATICA. (Bunch grass.)

A coarse perennial grass, growing in large tufts, usually in sandy ground in the Rocky Mountains at various altitudes, also in California,

Oregon, and British America. It furnishes an abundant coarse forage in the regions where it is found. The culms are from 1 to 2 feet high, erect, rigid, and leafy; the radicle leaves are frequently as long as the culm, two or three lines wide, sometimes flat, but generally involute and rigid. The culm leaves are from 3 to 6 or 8 inches long, rigid and rough. The panicle is narrow and spike-like, 3 to 5 inches long, erect, rather dense, sometimes interrupted below, and varying from pale green to purple. The branches are mostly in fives, very short and rough. The spikelets are about a quarter of an inch long, on short, rough pedicels; the outer glumes are nearly equal, ovate-lanceolate, long and sharp pointed, the upper one three-nerved, the lower one-nerved. The flowering glume is about one-third shorter, of similar texture, three-nerved, four-toothed at the apex, and bearing on the back a twisted and bent awn longer than the glume. The hairs at the base are scanty and short, those of the rudiment about half as long as the flower. The palet is about half as long as its glume, thin, two-nerved, and two-toothed at the apex. (Plate 60.)

DEYEUXIA HOWELLII. (Howell's grass.)

Culms densely tufted, 1 to 2 feet high, erect or somewhat geniculate below, smooth; radical leaves numerous, as long as the culm, firm, but not rigid, inclined to be involute, the ligule conspicuous. about one and one-half lines long, scarious; culm with three or four leaves which are 4 to 6 inches long, the upper one nearly equaling the culm. Panicle pyramidal, loose and spreading, 3 to 4 inches long, the branches mostly in fives, the lower ones 1 to 1½ inches long, numerously flowered above the middle. Spikelets pale green or tinged with purple, outer glumes lanceolate, acute, two and one-half to three lines long, nearly equal, membranaceous, the upper three-nerved, the lower one-nerved; flowering glume slightly shorter than the outer ones, lanceolate, acute, three to five nerved, the apex bifid, usually with four mucronate points, a conspicuous strong awn one-half inch long, inserted on the back about the lower third, a tuft of short hairs, and a hairy pedicel about half as long as the floret; palet nearly as long as its glume, thin, acute, and two-toothed at the apex.

This grass has recently been discovered in Oregon by Mr. T. J. Howell, and also in Washington Territory by Mr. W. N. Suksdorf. From its habit of growth and the great abundance of foliage, it gives promise of being a valuable grass for cultivation. (Plate 61.)

AMMOPHILA.

This genus differs very little from *Deyeuxia*, but chiefly in the absence of the awn on the back of the flowering glume.

AMMOPHILA ARUNDINACEA. (Sea-sand reed, Beach grass, Mat grass.)

This is the *Calamagrostis arenaria* of the olden books. The entire plant is of a whitish or pale-green color. It grows on sandy beaches

of the Atlantic at least as far south as North Carolina, and on the shores of the Great Lakes, but has not so far been recorded from the Pacific coast. It also grows on the sea-coast of the British Isles and of Europe. It forms tufts of greater or less extent, "its long creeping roots extending sometimes to the extent of 40 feet, and bearing tubers the size of a pea, interlaced with death-like tenacity of grasp, and form a network beneath the sand which resists the most vehement assaults of the ocean waves." The culms are from 2 to 3 feet high, rigid and solid; the leaves long, involute, smooth, rigid, and slender-pointed; the panicle dense, 6 to 10 inches long, close and spike-like; the spikelets are about half an inch long, compressed, crowded on the very short branchlets. The outer glumes are nearly equal, five to six lines long, compressed, lanceolate, chartaceous, smooth except on the thin keel; the flowering glume is a little shorter, acute or slightly mucronate at the tip, obscurely five-nerved; the palet about as long as its glume, two-keeled. The hairs at the base are rather scanty, and about one-third as long as the flowering glume; the hairy pedicel is of about the same length. This grass has no agricultural value, but from time immemorial its utility in binding together the loose sands of the beach and restraining the inroads of the ocean has been recognized and provided for in some places by law. Mr. Flint, in his work on grasses, says that the town and harbor of Provincetown, once called Cape Cod, where the Pilgrims first landed, one of the largest and most important harbors in the United States, sufficient in depth for ships of largest size, and in extent to anchor three thousand vessels at once, owe their preservation to this grass. The usual way of propagating the grass is by transplanting the roots. The grass is pulled up by hand and placed in a hole about a foot deep and the sand pressed around it by the foot. There are undoubtedly many places on the sea-coast where this grass would be of inestimable value in restraining the encroachment of the ocean. It would also be useful in forming a dense turf for the protection of dikes and banks subject to water-washing.

AMMOPHILA LONGIFOLIA.

This grass, formerly called *Calamagrostis longifolia*, has recently been transferred by Mr. Bentham to genus *Ammophila*. It grows on the sandy plains of the interior from British America to Arizona, and on the borders of the Great Lakes. It has strong running root-stalks, like the preceding, but is much taller, the culms being 3 to 6 feet high, stout and reed-like; the leaves long, rigid, and becoming involute, with a long thread-like point. The panicle is quite variable, from 4 to 16 inches long, at first rather close, but becoming open and spreading, the branches in the smaller forms being 2 or 3 inches long, and in the larger ones often 10 or 12 inches and widely spreading. The outer glumes are lanceolate, unequal, smooth, and chartaceous, the upper one three to four lines long, the lower about one-fourth shorter.

The flowering glume and palet are of equal length and similar texture with the longest outer glume; the copious hairs at the base are more than half as long as the flower. There is no sterile pedicel or rudiment. This grass is too coarse to be of much agricultural value, but would be useful for the same purposes as the preceding.

DESCHAMPSIA. (Aira of the books.)

This genus has two-flowered spikelets, the upper flower usually smaller than the lower, generally in a loose panicle with slender branches. The axis or stem connecting the two flowers is hairy, and is extended into a hairy pedicel which rarely bears an empty glume or rudiment of another flower. The outer glumes are keeled, rather thin, and with scarious margins; the flowering glumes have a fine awn on the back below the middle.

DESCHAMPSIA CÆSPITOSA (*aira cæspitosa*). (Hair grass.)

This is an exceedingly variable species, having a very wide distribution in this and other countries. It is somewhat rare east of the Mississippi, but on the elevated plains and in the Rocky Mountains, also in California and Oregon, it is one of the common bunch grasses which afford pasturage to cattle and horses. In the East it is found in the hilly regions of New England and the Alleghanies.

The culms form tussocks, are smooth, and grow from 2 to 4 feet high; the root leaves are very numerous, generally flat, narrow, and from 6 inches to a foot long; those of the culm about 2, and from 1 to 3 inches long; the ligule is conspicuous and pointed. The panicle is generally pyramidal, 4 to 6 or sometimes 10 inches long, the branches distant, 1 to 3 inches long; capillary and spreading, the lower ones in fives, those above two or three together, or single, and are flower-bearing mostly above the middle. The spikelets are smooth, on slender pedicels, and are about two lines long. The empty glumes are membranaceous, purple, or yellowish, nearly equal, the upper one a little the longer and about as long as the flowers; the flowering glumes are oblong, toothed at the obtuse apex, thin, scarious margined and delicately nerved; from the back near the base proceeds a slender awn about as long as the glume. The palets are similar in texture, narrow, two-nerved and two-toothed at the apex.

The panicle is very handsome, presenting a purple or glossy hue and a loose graceful appearance.

We know very little as to the value of this grass. It may be found worthy of cultivation in the arid interior districts. (Plate 62.)

DESCHAMPSIA FLEXUOSA. (Wood hair grass.)

A perennial grass, growing in tufts on rocky hills or in sandy woods. The culms are slender, 1½ to 2 feet high, and smooth. The leaves are mostly from the root, very numerous, very narrow, involute, and 6 to

12 inches long. The panicle is rather looser, and with longer, more naked branches, and fewer flowers than the preceding species. The branches are two to three together at the joints; the spikelets are of about the same size, on longer pedicels, the awn of the flowering glume about half longer, becoming bent and twisted. Sheep are fond of this grass, and where they have access to it, gnaw it close to the ground. It affords, however, but a small amount of feed, and is undeserving of cultivation.

DESCHAMPSIA DANTHONIOIDES. (*Aira danthonioides.*)

A slender annual grass, common in Oregon and California, growing in moist meadows, where, according to Mr. Bolander, it often forms a large portion of the herbage.

From its slender culms and small leaves it cannot furnish a large bulk of hay. The culms vary from 3 inches to a foot or 2 in height, sometimes bent and branching at the base. The leaves are 1 or 2 inches long and very narrow; the upper sheaths are very long. The panicle is loose, very slender, erect, usually 2 to 5 inches long, the lower branches in twos or threes, the upper ones in pairs or solitary, distant, appressed, branching from below the middle, and two-flowered. The spikelets are on slender pedicels. The outer glumes are about three lines long, lanceolate, gradually sharp-pointed, three-nerved, and slightly roughed on the keel. The two flowers are together, shorter than the outer glumes, being each about one line long, with a small tuft of silky white hairs at the base. The flowering glumes have a truncated apex with four small teeth, and the awn, which is inserted on the back about the middle, is three or four times as long as the glume, and usually more or less twisted and bent. (Plate 63.)

HOLCUS LANATUS. (Velvet grass, Meadow Soft grass, Velvet Mesquite grass.)

A foreign grass, which has been introduced and has become tolerably well established in many places. It is a perennial, with a stout, erect culm, 2 to 3 feet high, the leaves, and especially the sheaths, densely clothed with soft hairs feeling like velvet. The culm is leafy and the sheaths loose; the upper ones longer than the blade, which is three to six lines wide, 4 to 5 inches long, and rather abruptly pointed. The panicle is open and spreading, rather oblong in outline, and 4 to 6 inches long. The branches are mostly in twos or threes, much divided, and softly pubescent. The spikelets are two-flowered, the lower one being the larger and containing both stamens and pistils, the upper one small and staminate only. The outer glumes are about two lines long, membranaceous, boat-shaped, sparingly pubescent, and white, the upper one broader and three nerved, the lower one-nerved, both much longer than the flowers. The flowering glumes are smooth and shining, thicker

than the outer glumes, the lower flower awnless, the upper one with a short, stout, bent, or hooked awn at the apex.

This grass is not held in good repute as an agricultural grass in Europe. In this country, especially at the South, it has frequently been favorably spoken of. Professor Phares says:

It luxuriates in moist, peaty lands, but will grow on poor, sandy, or clay hill lands, and produce remunerative crops where few other plants will make anything. It has been cultivated in North Carolina on such land, and after cutting and allowed to grow again, plowed under with so much advantage that other crops were subsequently produced. Hon. H. W. L. Lewis, of Louisiana, has cultivated this grass many years with great satisfaction. It is by no means the best of our grasses, but best for some lands, and on such lands more profitable than other grasses. It seems to have been greatly improved by acclimating in Texas and other Southern States, and this is true of some of the other grasses and forage plants.

(Plate 64.)

TRISETUM.

This genus is characterized as having the spikelets two to three and, rarely, five flowered, the axis usually hairy, and at the base of the upper flower extended into a bristle; the outer glumes unequal, acute, keeled, membranaceous, with scarious margins; the flowering glumes of similar texture keeled, acute, the apex two-toothed, the teeth sometimes prolonged into bristle-like points, the central nerve furnished with an awn above the middle, which is usually twisted and bent in the middle; the palet hyaline, narrow, two-nerved, two-toothed.

TRISETUM PALUSTRE.

A slender grass, usually about 2 feet high, growing in low meadows or moist ground throughout the Eastern part of the United States. The culms are smooth, with long internodes and few linear leaves, 2 to 4 inches long; the panicle is oblong, 3 to 4 inches long, loose and gracefully drooping, the branches two to five together, rather capillary, 1 to 1½ inches long, and loosely flowered; the spikelets are two-flowered; the outer glumes are about two lines long, the lower one one-nerved, the upper rather obovate and three-nerved; the lower flower is commonly awnless or only tipped with a short awn; the second flower is rather shorter and with a slender, spreading awn longer than the flower.

This is a nutritious grass, but is seldom found in sufficient quantity to be of much value. (Plate 65.)

TRISETUM CERNUUM.

This grass grows to the height of 2 or 3 feet, with flat wide leaves, which are about 6 inches long, and with an open, spreading, and drooping panicle, 6 to 9 inches long; the branches are slender, solitary, or sometimes clustered below, and much subdivided above the middle. The spikelets vary from three to six lines in length and have two to three or, rarely, four flowers in each. The outer glumes are very unequal, the

lower one being very narrow and awl-shaped, the upper one broad, three-nerved, obtuse, and tipped with a fine point, and longer, sometimes twice as long as the lower.

The flowering glume has two slender pointed teeth, and on the back, near the apex, a slender awn twice its length.

Of this grass Mr. Bolander says that it deserves further attention. It grows on dry hill-sides near the Bay of San Francisco and the Oakland hills, and also extends northward to Oregon. (Plate 66.)

TRISETUM SUBSPICATUM.

A perennial grass of the mountainous regions of Europe and North America. It is found sparingly in New England, on the shores of Lake Superior, in the Rocky Mountains of Colorado, Utah, California, Oregon, and northward to the Arctic circle. It varies in height according to the altitude at which it grows, being sometimes reduced to 3 or 4 inches, at other times running up to 2 feet high. The culms are erect and firm, smooth, or downy. The panicle is spike-like, dense, and cylindrical or elongated, and more or less interrupted, generally of a purplish color. The spikelets are two to three flowered. The flowers are slightly longer than the outer glumes, slightly scabrous, the flowering glumes acutely two toothed at the apex, and bearing a stout awn which is longer than its glume.

This undoubtedly furnishes a considerable portion of mountain pasturage. (Plate 67.)

AVENA. (Oats and Oat grass.)

This genus is closely related to *Trisetum*, the spikelets are larger and two to five flowered, the uppermost one generally imperfect; the axis is hairy below the flowers, the outer glumes nearly equal; the flowering glumes of firmer texture (in some species cartilaginous), shortly two-toothed at the apex, and with a long twisted awn below the point.

AVENA FATUA. (Wild oats.)

This species is very common in California. It is generally thought to have been introduced from Europe, where it is native, but it has become diffused over many other countries, including Australia and South America. It is thought by some to be the original of the cultivated oat, *Avena sativa*, that the common oat will degenerate into the wild oat, and that by careful cultivation and selection of seed the wild oat can be changed into the common cultivated oat. But on this question there is a conflict of opinions, and the alleged facts are not sufficiently established. The wild oat differs from the cultivated one chiefly in having more flowers in the spikelets, in the long brown hairs which cover the flowering glumes, in the constant presence of the long twisted awn, and in the smaller size and lighter weight of the grain. It is a great injury to any grain-field in which it may be introduced, but for

the purpose of fodder, of which it makes a good quality, it has been much employed in California.

It is stated above "that the common cultivated oat is believed sometimes to degenerate into the wild oat." The following case. described by Mr. J. G. Pickett, of Pickett's Station, Wis., certainly seems to afford evidence to that effect. The circumstance can only be otherwise accounted for by supposing the accidental introduction of the wild oat through seed obtained from some foreign source. It also shows how easily this pest is spread after once being introduced into a field. Mr. Pickett writes as follows:

Inclosed I send you specimens of a plant known in this section as wild oats. The history of the plant is as follows: In the year 1856 Mr. Lucius Hawley, of this town, threshed with a machine about 15 acres of common white oats from the stack, upon the ground where the crop grew. The straw was indifferently piled up, and so remained through the winter. In the following spring the straw was set on fire, but being wet was but partially burned, and what remained was scattered over about an acre of ground, and, with the balance of the field, was plowed under, and the field sown to spring wheat. At harvest time the threshing ground and the land upon which the partially burned straw had been drawn was found to be completely occupied by a crop of oats, and so thick upon the ground as to have completely smothered the wheat. Mr. Hawley, supposing the oats were from those of the former crop, did not examine the grain closely, but cut the wheat and oats with a reaper, at the same time keeping the grains separate as much as possible, and he did not discover until stacking the grain that the oats were not the common oats, but something different from any he had seen before. The oats ripening early, had shelled upon the reaper, and were carried more or less over the entire field, and a crop of spring wheat again following, the new oats were found scattered over the whole field. This was the first known of this pest here, and up to this time (March, 1882) it has continued to spread over the country by being mixed with seed wheat and oats, and transported from farm to farm by threshing-machines until the damage done can hardly be estimated. It will effectually run out any crop and take entire possession of the soil. Seeding down the land for three or four years will eradicate the grain, and this is the only remedy yet found. This oat is a winter grain and will not germinate and grow until it has laid in or upon the ground over winter and been frozen. I have known a field of 40 acres sown in the spring with clean wheat seed and nothing else, from which was threshed 600 bushels of these oats, and wheat about equaling the amount of seed sown. The oat, while growing, looks precisely like the common oat, but ripens early and shells easily. The kernel, when ripe, is nearly black, and has attached to it a spiral barbed tail, by which it attaches itself to clothing, grain-bags, and to every crevice about a threshing-machine, fanning-mill, or reaper, and will even penetrate the skins of animals. When cleaned the grain weighs from 12 to 18 pounds per bushel, and it is only used by finely grinding the grain for stock, or by cutting, before ripening, for hay, of which it makes a good quality. My own theory of its origin is that by the action of fire and the winter exposure the common oat on the farm of Mr. Hawley changed its variety and nature into this wild winter oat, which is now the worst pest this part of Wisconsin has yet known.

(Plate 68.)

AVENA STRIATA. (Wild oat grass.)

Grows on rocky hills in New England, New York, and northwestward. The culms are about 2 feet high, smooth and slender. The leaves are narrow and 4 to 6 inches long; the panicle is slender, 4 to 5

inches long, open and drooping; the upper branches are single and undivided, each with a single spikelet, the lower branches are in twos or threes, with longer pedicels, and sometimes having two or three spikelets. The spikelets are one-half to three-fourths inch long, and from three to six flowered. The outer glumes are much shorter than the spikelet, thin, scarious on the margins, acute, and purplish. Each of the flowers has a short tuft of hairs at the base. The lower palet is four lines long, seven nerved, sharply two toothed at the apex, just below which rises a slender bent awn. All the flowers of the spikelet are alike, except that the upper ones are smaller. This grass is related to the cultivated oats. Its range is to the northward, being addicted to a cool, elevated country. Its productiveness and value for agricultural purposes has not been tested. (Plate 69.)

Avena pratensis and *Avena flavescens* are two species of Europe, which have been cultivated to some extent in that country, but are little known here.

ARRHENATHERUM AVENACEUM. (Evergreen grass, Tall oat grass, Meadow oat grass.)

A perennial grass of strong, vigorous growth, introduced from Europe, and sparingly cultivated. Culms, 2 to 4 feet high, erect, rather stout, with four or five leaves each; the sheaths smooth, the leaves somewhat rough on the upper surface, 6 to 10 inches long, and about three lines wide, gradually pointed. The panicle is loose, rather contracted, from 6 to 10 inches long, and rather drooping; the branches very unequal, mostly in fives, the longer ones 1 to 3 inches, and subdivided from about the middle; the smaller branches very short, all rather full-flowered. The spikelets are mostly on short pedicels. The structure of the flowers is similar to that of common oats, but different in several particulars. The spikelets consist of two flowers, the lower of which is staminate only, the upper one both staminate and pistillate; the outer glumes are thin and transparent, the upper one about four lines long and three-nerved, the lower one nearly three lines long and one-nerved. The flowering glume is about four lines long, green, strongly seven-nerved, lanceolate, acute, hairy at base, roughish, and in the lower flower gives rise on the back below the middle to a long, twisted, and bent awn; in the upper flower the glume is merely bristle-pointed near the apex. The palet is thin and transparent, linear, and two-toothed. This grass is much valued on the continent of Europe. The herbage is very productive and its growth rapid. When growing with other grasses cattle and sheep eat it very well, but do not like to be confined to it exclusively.

Mr. Thomas Brigden, of South Lowell, Ala., says, respecting this grass:

We obtained seed from the Tennessee Valley under the name of evergreen grass, and it appears at the present time to be by far the most valuable kind that we have ex-

perimented with; it remains green during the winter, and starts into growth very early in the spring, making a dense, heavy growth from 20 to 30 inches high, and, as far as at present tested, it stands the summer heat well.

Professor Phares, of Mississippi, says:

It is widely naturalized and well adapted to a great variety of soils. On sandy or gravelly soils it succeeds admirably, growing 2 to 3 feet high. On rich, dry upland it grows from 5 to 7 feet high. It has an abundance of perennial, long fibrous roots penetrating deeply in the soil, being therefore less affected by drought or cold, and enabled to yield a large quantity of foliage, winter and summer. These advantages render it one of the very best grasses for the South, both for grazing, being evergreen, and for hay, admitting of being cut twice a year. It is probably the best winter grass that can be obtained. It will make twice as much hay as timothy. To make good hay it must be cut as soon as it blooms, and after cut, must not be wet by dew or rain, which damages it greatly in quality and appearance. For green soiling it may be cut four or five times with favorable seasons. In from six to ten days after blooming the seeds begin to ripen and fall, the upper ones first. It is therefore a little troublesome to save the seed. As soon as those at the top of the panicle ripen sufficiently to begin to drop the seeds should be cut off and dried, when the seeds will all thresh out readily and be matured. After the seeds are ripe and taken off the long abundant leaves and stems are still green, and being mowed make good hay. It may be sown in March or April and mowed the same season; but for heavier yield it is better to sow in September or October. Not less than 2 bushels (14 pounds, per acre should be sown. The average annual nutriment yielded by this grass in the southern belt is probably twice as great as in Pennsylvania and other Northern States.

Mr. Charles L. Flint says:

It produces an abundant supply of foliage, and is valuable for pastures on account of its early and luxurious growth. It grows spontaneously on deep, sandy soils when once naturalized. It has been cultivated to some extent in New England, and was at one time highly esteemed, mainly for its early, rapid and late growth, making it well calculated as a permanent pasture grass. It will succeed on tenacious clover soils.

(Plate 70.)

DANTHONIA.

This genus is related to *Avena* and characterized as follows: Spikelets three to five or many-flowered, the axis hairy and produced beyond the flowers in a stipe or imperfect flower; outer glumes narrow, keeled, acute, usually as long as the spikelet; flowering glumes of firmer texture, convex on the back, seven to nine nerved, with two rigid or scarious terminal teeth or lobes, and with a flatish, twisted, and bent awn between the teeth. This awn is composed by the union of the middle and two of the lateral nerves.

DANTHONIA SPICATA. (Spiked Wild Oat grass.)

This species grows in small clumps on barren hills or in poor clay lands. The leaves are mostly in a tuft near the ground, short, narrow, and curled in dry weather. The culms are from 1½ to 2 feet high, erect and slender. The panicle is only an inch or two long, mostly simple, and of four to seven spikelets, with very short pedicels. The spikelets

are about five-flowered, the flowering glume loosely hairy, with the teeth about one-fourth its length and very acute.

It is a grass of very little value.

Hon. J. S. Gould says:

As it will grow on hard clay lands where nothing else will, it might be worth while to sow its seeds on such lands, as it is certainly better than nothing; but the better plan is to manure the soil so that it will produce the richer grasses.

(Plate 71.)

DANTHONIA COMPRESSA. (Mountain Oat grass.)

This species grows in Pennsylvania, New York, and New England. Mr. C. G. Pringle sends it from Vermont growing on dry hillocks along the Waterbury River. It also grows on the summit of the Roan Mountains, North Carolina, over large areas, and furnishes good summer pasturage. Probably it occurs on the other mountains of the Alleghany range. It differs from the preceding in forming a compact sod, by having more numerous and larger leaves, by a larger, longer, and spreading panicle, and by the longer, more slender awn-pointed teeth of the flowering glumes. (Plate 72.)

DANTHONIA SERICEA. (Silky-flowered, Oat grass.)

A perennial grass, 2 to 3 feet high, growing in open, sandy woods, with numerous long, slender, radical leaves, and three or four similar ones on the stem, the sheaths soft, hairy the ligule a mere hairy fringe; culms smooth, flexible; panicle loose and rather contracted, 3 to 4 inches long, and 1 or 2 inches wide; the branches single at the joints, and subdivided from the lower third into a few branchlets, each with one to three spikelets. The spikelets are about seven-flowered, the flowers closely packed and silky hairy; the outer glumes are smooth, half an inch or more in length, longer than all the flowers in the spikelet, linear-lanceolate, the lower one two-nerved and the upper one three-nerved. The flowering glumes are about three lines long, five to seven nerved, the awl-pointed teeth very slender and nearly as long as the rest of the glume, with the middle awn six or seven lines long, sparsely hairy on the back, and copiously white silky on the margins below. This species appears to be confined to the Atlantic States. Its value has not been tested. (Plate 73.)

DANTHONIA CALIFORNICA. (The California Oat grass.)

A perennial grass of California, Oregon, the Rocky Mountains, and Manitoba; not very common, variable in height, usually 1 to 2 feet, with narrow, convolute and long-pointed root-leaves, those of the culm somewhat wider, 3 or 4 inches long, the lower sheaths hairy, especially at the throat. The panicle usually consists of three to five spreading branches, each of which is terminated by a single spikelet. The spikelets are five to seven flowered, widening upwards. The outer glumes are about three-quarters of an inch long, linear-lanceolate, acute, five to seven

nerved, and purplish. The flowers are somewhat crowded on the axis. The flowering glumes are broad, obscurely nine-nerved, smooth on the back, the margins below fringed with long, silky hairs, the narrow, stiff, awned-teeth about half as long as the glumes (four or five lines). This is a somewhat ornamental grass, but probably not of much agricultural value. (Plate 74.)

CYNODON DACTYLON. (Bermuda grass.)

A low, creeping perennial grass, with abundant short leaves at the base, sending up slender, nearly leafless flower stalks or culms, which have three to five slender, diverging spikes at the summit. The spikelets are sessile in two rows on one side of the slender spikes; they each have one flower with a short pediceled, naked rudiment of a second flower; the outer glumes nearly equal, keeled; the flowering glume boat-shaped, broader and prominently keeled; the palet narrow and two-keeled. This grass is a native of Southern Europe and of all tropical countries. It is a common pasture grass in the West Indies. In the Southern States it has long been a chief reliance for pasture, has been extravagantly praised by some and cursed by others who find it difficult to eradicate when once established. Its properties have been very fully discussed in Southern journals. It rarely ripens any seed, and the usual methods of reproducing is to chop up the roots with a cutting knife, sow them broadcast, and plow under shallow.

Col. T. C. Howard, of Georgia, says:

The desideratum to the South is a grass that is perennial, nutritious, and adapted to the climate. While we have grasses and forage plants that do well when nursed, we have few that live and thrive here as in their native habitat. The Bermuda and crab grasses are at home in the South. They not only live, but live in spite of neglect, and when petted and encouraged they make such grateful returns as astonish the benefactor.

Professor Killebrew, of Tennessee, says:

In Louisiana, Texas, and the South generally it is and has been the chief reliance for pasture for a long time, and the immense herds of cattle on the southern prairies subsist principally on this food. It revels in sandy soils, and has been grown extensively on the sandy hills of Virginia and North and South Carolina. It is used extensively on the southern rivers to hold the levees and embankments of the roads. It will throw its runners over a rock 6 feet across and soon hide it from view, or it will run down the sides of the deepest gully and stop its washing. Hogs thrive upon its succulent roots, and horses and cattle upon its foliage. It has the capacity to withstand any amount of heat and drought, and months that are so dry as to check the growth of blue grass will only make the Burmuda green and the more thrifty.

Professor Phares, of Mississippi, says:

As a permanent pasture grass, I know of no other that I consider so valuable as this, after having transferred it from near the mouth of the Red River to my present residence thirty-five years ago, and having studied it on hundreds of other farms, commons, and levees for a longer period. To make good hay and the largest yield, this

grass must be mowed from three to five times every summer. Thus briers, broom grass, and other weeds are repressed and prevented from seeding, multiplying, and ruining the meadow.

Respecting the difficulty of eradicating this grass from ground wanted for other cultivation, Colonel Lane, of Georgia, says:

Upon our ordinary upland I have found no difficulty in destroying it by close cultivation in cotton for two years. It requires a few extra plowings to get the sod thoroughly broken to pieces.

(Plate 75.)

CHLORIS ALBA.

An annual grass, growing in tufts, 1 to 2 feet high, smooth, the culms frequently-branched and bent at the lower joints, decumbent, becoming erect; leaves numerous, smooth, the sheaths mostly loose, the blade broad, the upper sheath dilated and at first inclosing the flower spikes, which are eight to fifteen in number, 2 to 3 inches long, and umbellate or fasciculate at the top of the culm or of the lateral branches. The spikelets are sessile and crowded in two rows on one side of the spikes; each spikelet contains one perfect and one or two imperfect or rudimentary flowers; the outer glumes are unequal, thin, keeled, the upper one mucronate-pointed, and about one and one-half lines long, the lower one one-third shorter; the flowering glume of the lower or perfect flower is thick and firm in texture, nearly one and one-half lines long, broad in the middle and narrowed above and below, much compressed, five nerved, with two short teeth at the apex, and a straight awn two or three lines long between the teeth, the margins toward the top strongly ciliate with long white hairs; the palet is of similar texture, narrow, and nearly as long as its glume; the neutral or upper flower is shorter, truncate above, of a club-like appearance, smooth, tipped with an awn. Sometimes there is another small imperfect flower or a pedicel above the second, and enwrapped by it.

This is a common grass in the arid regions of New Mexico, Arizona, and farther south and west. This grass furnishes a large quantity of foliage, but of its agricultural value we have no information. There are several other species growing in the same region. (Plate 76.)

BOUTELOUA. (Mesquite grass.)

This genus, of which there are many species, has generally numerous spikes in a racemose one-sided panicle. The spikes are generally densely flowered and from one-half to 1½ inches long. The spikelets are crowded in two rows on one side of the axis, each consisting of one perfect flower, and a stalked pedicel bearing empty glumes and one to three stiff awns; the outer glumes are unequal, acute, keeled, membranaceous; the flowering glume broader and usually thicker, with three to five lobes, teeth or awns at the apex; palet hyaline, narrow, entire or two-toothed, enfolded by its glume.

BOUTELOUA OLIGOSTACHYA. (Mesquite grass, Gramma grass, Buffalo grass.)

This is a perennial species growing on the great plains from Montana and Dakota southward to Texas. The culms are from one-half to 1½ feet high. Near the top there are usually two or three, sometimes more, curved flowering spikes, about 1½ inches long; the culm and leaves are smooth; the outer glumes and the flowering glumes are sparingly soft-hairy, the lobes awl pointed, the sterile flower or rudiment is copiously villous-tufted at the summit of the naked pedicel, its three awns equaling the perfect flower. (Plate 77.)

BOUTELOUA HIRSUTA. (Bristly mesquite or Gramma grass.)

This annual or biennial species has about the same range as the preceding, is of about the same size and general appearance. The upper empty glume is on the back hispid with bristly hairs proceeding from dark, warty glands; the flowering glume is pubescent, three-cleft into awl-pointed lobes; the sterile flower and its pedicel are glabrous, the three sterile awns longer than the fertile flower.

BOUTELOUA POLYSTACHYA. (Low Gramma grass.)

This species probably does not reach farther north than northern New Mexico. It is an annual from 6 to 10 inches high growing in clumps; the culms are slender, branching and bent at the lower joints. The culm terminates in a raceme-like panicle, 3 to 6 inches long, composed of five to seven alternate, narrow, one-sided spikes, which are about 1 inch long and one-half inch to 1 inch apart. The spikelets are generally close but not so dense as in the preceding, and much smaller; the outer glumes are thin, unequal, oblong, the upper one about one line long, bifid and mucronate pointed; the flowering glume of the perfect flower is oblong, obtuse, three-nerved, the nerves extended beyond the glumes into short awns, with two broad lobes, one on each side of the central awn, and two shall lateral lobes, one on the outer side of each lateral awn, the outer margins ciliate. The rudimentary flower is very short stalked, with three small glume-like scales and three short awns. There are several varieties or forms of this species, some smaller and some larger. It abounds near the banks of streams and furnishes excellent pasturage. (Plate 78.)

BOUTELOUA RACEMOSA, (*B. curtipendula*, GRAY). (Tall Gramma grass.)

This species ranges from Mexico to British America, and east of the Mississippi River in Wisconsin and Illinois. It is easily distinguished from the others by its taller growth, and by the long, slender raceme of twenty to fifty or more slender spikes. These are usually about half an inch long and reflexed. There are from six to ten spikelets on each spike. The outer glumes are lanceolate, acuminate; the upper about two lines long and scabrous; the flowering glume is oblong, between

two to three lines long, with three short awl-pointed teeth at the apex; the palet is nearly of equal length; the sterile flower is reduced to one or two minute scales with three short awns, or to a single small awn.

The most useful of the gramma grasses is, probably, the *Bouteloua oligostachya*, but the others aid in furnishing the supply of food for the thousands of animals which are fattened on the great plains. It is doubtful if these grasses would bear the effect of continued tramping and close cropping if the lands were inclosed and pastured.

ELEUSINE INDICA. (Yard grass, Crow-foot, Crab grass, Wire grass.)

An annual grass belonging to tropical countries, but now naturalized in most temperate climates. In the Southern States it is found in every door-yard and in all waste places. The culms are from 1 to 3 feet high, usually coarse and thick, and very leafy, especially below. The leaves are long and rather wide. At the top of the culm there are two to five or more thickish, densely-flowered spikes proceeding from a common point, with sometimes one or two scattering ones lower down on the culm. The spikelets are sessile and crowded along one side of the axis, each being from two to six flowered, the upper flower imperfect or rudimentary; the outer glumes are membranaceous, shorter than the flowers, the flowering glumes usually obtuse; the palet folded and two-keeled.

Professor Phares, of Mississippi, says:

The clumps have many long leaves and stems, rising 1 or 2 feet high, and many long, strong, deeply penetrating fibrous roots. It grows readily in door-yards, barn-yards, and rich cultivated grounds, and produces an immense quantity of seeds. It is a very nutritious grass, and good for grazing, soiling, and hay. The succulent lower part of the stems, covered with the sheaths of the leaves, renders it difficult to cure well, for which several days are required. It may be cut two or three times, and yields a large quantity of hay.

(Plate 79.)

LEPTOCHLOA MUCRONATA. (Feather grass, Slender grass.)

An annual grass, growing from 2 to 3 feet high, the flowers arranged in a long panicled, loose raceme. The branches or spikes are very slender, 1 to 5 inches long, and very numerous, thirty to fifty or more, with the spikelets sessile and continuous in two rows along one side of the spikes. The spikelets are about one line long, three-flowered, the uppermost flower imperfect. The outer glumes are lanceolate, acute keeled, and nearly as long as the spikelet; the flowering glumes are obtuse or sometimes slightly mucronate, one-half line long, keeled, and with strong, somewhat pubescent, lateral nerves.

This is a handsome grass when full grown, the panicles on thrifty specimens becoming 2 feet long, the slender branches arranged along the main stem in a feather-like manner, hence the name. It grows from Virginia, west and south, becoming quite common in the South-

ern States. It affords a small amount of grazing during the summer. Professor Phares says:

Its growth is very rapid, although it has little root and is easily uprooted. Although it contains a good percentage of nutritious matter, it is of little agricultural value. Its assurgent leaves and stems and immensely large panicles occupy so much space that a comparatively small number of plants would occupy an acre of ground, while it has so little weight that the product of several acres of the finest growth of it would be required to produce a single ton of hay.

(Plate 80.)

BUCHLOË DACTYLOIDES. (Buffalo grass, False Mesquite grass.)

This grass is extensively spread over all the region known as the great plains. It is very low, the bulk of leaves seldom rising more than 3 or 4 inches above the ground, growing in extensive tufts or patches, and spreading largely by means of stolons or offshoots similar to those of Bermuda grass, these stolons being sometimes 2 feet long, and with joints every 3 or 4 inches, frequently rooting and sending up flowering culms from the joints. The leaves of the radical tufts are 3 to 5 inches long, one or one-half line wide, smooth, or edged with a few scattering hairs. The flowering culms are chiefly diœcious, but sometimes both male and female flowers are found on the same plant but in separate parts. The flowering stems of the *male* plant are 4 to 8 inches high, bearing three or four slender leaves, and at the summit two to four short contiguous spikes, which are about half an inch long. These spikes consist usually of five to six sessile spikelets, alternate, in two rows, on the lower side of the flattened, scabrous axis. The spikelets are two to three lines long and mostly two-flowered. The outer glumes are unequal and one-nerved, the lower one half as long as the flower above it, the upper one shorter. The flowering glumes and palets are of equal length, membranaceous, the flowering glume three-nerved, the palet two-nerved. The flowering stalk of the *female* plant is shorter than the leaves, 1 to 2 or sometimes 3 or 4 inches high, sometimes almost concealed among the leaves at the joints of the stolons. The sheaths of the two or three uppermost leaves of the culm are dilated and inclose the spikes or clusters of flowers. Of these spikes there are two or three, each consisting of three to five spikelets. The spikelets are single-flowered and of a somewhat complex structure, the parts analagous to those of the male flowers, but thickened, indurated, and modified. All the upper glumes are indurated and united at their bases with the thickened axis, the lower glume of the lowest spikelet being lanceolate, with an herbaceous tip or two to three cleft, thickened and united to the upper glume, the lower glume of the other spikelets free, much smaller, ovate-lanceolate, acute, and one-nerved, the flowering glume shorter, three-nerved, and three-toothed at the summit.

It is hardly necessary to recapitulate the virtues of this widely celebrated grass. It plays an important part in the feeding and fattening of the vast herds of cattle, which have now mostly displaced the buffalo, whose favorite food it was supposed to be.

Prof. S. B. Buckley, of Austin, Tex., says:

This is one of the best grasses of Texas for pasturage, if not the very best; being perennial it affords food for stock both summer and winter. Even in midwinter it presents a green covering over many hills and prairies in this vicinity. It is also the best grass for lawns indigenous to Texas. It thrives on every variety of soil, growing on poor gravelly uplands, and also in rich river bottoms, but it mostly abounds on the prairies, among the mesquite trees scattered over their surface, throughout a large portion of our State, whence it is commonly called mesquite grass in Texas. This name, however, is given to two or three other species of grass which are associated with it. It is not difficult to eradiate, nor is it ever troublesome in cultivated fields, because it has so few seeds. All kinds of stock are extremely fond of it, from which we infer that it is very sweet and nutritous. In extreme droughts all the grasses seem dead, but a rain will make this grass green and growing in a few hours. Even when dry, weather-beaten, and seemingly dead it is still good food for stock.

Whether this grass can be successfully subjected to cultivation remains to be seen. (Plate 81.)

TRIODIA. (*Tricuspis.*)

This genus, which contains numerous species of very different size and aspect, is characterized as follows: Spikelets, several to many-flowered, some of the upper ones male or imperfect; the outer glumes keeled, acute, or acutish, awnless; the flowering glumes imbricated, rounded on the back, at least below, three-nerved, the marginal nerves usually hairy, mucronate, three-toothed or three-lobed at the apex, or obscurely erose, often hardened and nerveless in fruit; the palet broad, prominently two-keeled.

TRIODIA SESLERIOIDES. (*Tricuspis seslerioides.*) (Tall Red top.)

This grass grows from 3 to 5 feet high. The culms are very smooth; the leaves are long and flat, the lower sheaths hairy or smoothish. The panicle is large and loose, at first erect, but finally spreading widely. The branches are single or in twos or threes below, and frequently 6 inches long, divided, and flower-bearing above the middle. The spikelets are on short pedicels, three to four lines long, and five or six flowered. The outer glumes are shorter than the flowers, unequal and pointed; the flowering glumes are hairy toward the base, having three strong nerves, which are extended into short teeth at the summit. It is a large and showy grass when fully matured, the panicles being large, spreading, and of a purplish color. It grows in sandy fields, and on dry sterile banks, from New York to South Carolina, and westward. This is eaten by cattle when it is young, but the culms are rather harsh and wiry and not relished by them. It is, however, cut for hay where it naturally abounds. (Plate 82.)

TRIODIA TRINERVIGLUMIS. (*Tricuspis trinerviglumis.*)

Another perennial species of this genus, growing in Colorado, Arkansas, Texas, New Mexico, and southward. The culms are 2 to 3 feet high, and rather stout; the radical leaves are somewhat rigid, 6 to 12

inches long, narrow, acuminate-pointed, inclined to be involute, the sheaths more or less hairy. The smooth culm has three or four leaves, which are 4 to 8 inches long, and slender-pointed. The panicle is narrow and spike-like, 6 to 9 inches long, composed of five or six alternate, somewhat distant, and closely erect branches, the lower ones 1 to 2 inches long, and consisting of six to ten sessile, alternate spikelets, each of which are eight to ten flowered, and four to six lines long. The outer glumes are lanceolate, acute, smooth, nearly equal, somewhat faintly three-nerved, and three to five lines long; the flowering glumes are oblong, three-nerved, two to three lines long, entire or obscurely denticulate at the apex, acute or obtusish, the nerves and margins densely hairy for about two-thirds the length, also the base and axis hairy. The palet is one-third shorter, two-keeled, minutely toothed at the apex, hairy on the keels below.

Little is known of its abundance or agricultural value. (Plate 83.)

Triodia stricta is another species of Texas and the Southwest, much larger, stouter, and more rigid than the preceding.

TRIODIA ACUMINATA. (*Tricuspis acuminata.*)

A low species, growing in tufts, from 6 to 12 inches high, the leaves short and narrow, but abundant near the ground; the culms are erect, slender, with one or two short leaves, and terminated by an oblong, spike-like panicle about an inch long, composed of a few crowded sessile or nearly sessile branches, each with one to three spikelets. The spikelets each contain eight or ten crowded flowers. The outer glumes are nearly equal, lanceolate, acute, chartaceous, one-nerved, about three lines long; the flowering glumes are about three lines long, lanceolate or ovate-lanceolate, acute, three-nerved, the mid-nerve extended into a short stiff awn, the margins fringed with long white hairs, and the back below, with the axis, hairy. The palet is about one-third shorter than its glume, folded back on the two keels, sparingly hairy, and the keels scabrous pubescent. This is a native of the arid regions of Texas, New Mexico, and southwestward. (Plate 84.)

TRIPLASIS PURPUREA. (*Tricuspis purpurea.*) (Sand grass.)

An annual grass, growing in tufts in sandy soil along the Atlantic coast, and also in sandy districts in the interior. The culms are about 1 foot high, rather decumbent at the base, with eight to ten short joints, and an equal number of narrow, awl-shaped leaves, 2 to 3 inches long, which are bearded with hairs at the top of the sheaths. There are usually several lateral panicles of flowers as well as a terminal one. The lateral ones are inclosed within the sheaths; the terminal one usually exerted, but short and simple. The spikelets are two to five flowered; the glumes much shorter than the spikelet; the flowers rather distant from each other; the flowering glumes and palets strongly fringed on

the nerves; the flowering glumes two-lobed or two-cleft at the summit, with the mid-nerve extended into a short awn between the lobes. This grass has very little practical value.

DIPLACHNE. (*Leptochloa.*)

This genus is characterized as having the spikelets narrow, sessile, or nearly so, on the long slender branches of the panicle, usually in two rows, but not continuous as in *Leptochloa*, the outer glumes keeled, acute, but not awned; the flowering glumes one to three nerved, with a thin or hyaline, shortly two-toothed or two-lobed apex, the keel produced into a short point or awn between the lobes; palet thin and prominently two-nerved.

DIPLACHNE FASCICULARIS. (*Leptochloa fascicularis.*) (Spike grass.)

An annual grass of vigorous growth, 2 to 3 feet high, growing in brackish marshes or wet ground near the sea-coast, and, also, far inland in the Mississippi Valley, Texas, Arizona, &c., in alkaline soil. The radical leaves are narrow and half to two-thirds as long as the culms, rough on the margin; those of the culms similar, with long, smooth, loose sheaths, the upper one usually inclosing the base of the panicle. The culms are frequently branched at the lower joints. The panicle is large, 6 to 10 inches long, consisting of numerous (fifteen to thirty) spike-like branches, which are 2 to 4 inches long, mostly alternate, sometimes fascicled below, angular and rough, and flower-bearing throughout. The spikelets are nearly sessile and alternate, usually somewhat longer than the space between them; each contains five to seven flowers; the outer glumes are unequal, smooth, one-nerved, and mucronate-pointed; the flowering are ovate-lanceolate, about one and a half lines long, flattish on the back, three-nerved, pubescent on the nerves and margins below, shortly two-toothed at the apex, with a short rough awn between the teeth; the palet is somewhat shorter, lanceolate, two-nerved, and ciliate on the nerves. (Plate 85.)

DIPLACHNE DUBIA. (*Leptochloa dubia.*)

A grass of similar aspect to the preceding; the leaves somewhat longer and more rigid; the panicle rather shorter, and composed of six to twelve branches, which are stouter and more spreading. The outer glumes are lanceolate, nearly equal, acute, one-nerved, rough on the keel, about one and one-half lines long; the flowering glumes are oblong, very obtuse, two-lobed and somewhat fringe-toothed at the apex, three nerved, smooth except on the margins, awnless; the palet is as long as its glume, narrower, two-nerved, and ciliate on the nerves. The spikelets in age become spreading, and the axis zigzag. It is of more southern range than he preceding, occurring in the Gulf States and southwestward. (Plate 86.)

PHRAGMITES COMMUNIS. (Reed grass.)

A tall, coarse, perennial grass, growing on the borders of ponds and streams, almost rivaling sorghum in luxuriance. It attains a height of 6 to 10 feet; the culms sometimes an inch in diameter, and leaves an inch or two in width. The panicle is from 9 to 15 inches long, loose but not much spreading, of an oblong or lanceolate form and slightly nodding. The branches are very numerous, irregularly whorled, 4 to 8 inches long, much subdivided, and profusely flowering. The larger panicles form very ornamental plumes, almost equal to those of *Arundo donax*, so much cultivated for ornamental purposes. The spikelets are three to seven flowered, all the flowers except the lowest surrounded by long silky hairs at the base; the lowest one is either empty or contains only stamens. The lower or empty glumes are thin, lanceolate, keeled, and unequal in size, the upper one being considerably the longer. The flowering glumes are membranaceous, narrowly awl shaped, and about as long as the silky hairs. The palets are thin and only half to one-third as long as their glumes.

This grass is widely distributed in different parts of the globe, and in some countries is put to several uses, as for thatching, for which it is said to be valuable. It is also sometimes used for making light reed fences and screens. Its leaves are too coarse and innutritious for fodder except when very young.

Professor Scribner saw in Montana prostrate stems of this grass which were 28 feet long, and some of the upright culms were 10 to 14 feet high. (Plate 87.)

KŒLERIA CRISTATA. (Crested Kœleria.)

This grass has a very wide diffusion both in this country and in Europe and Asia. It favors dry hills or sandy prairies, and on the great plains is one of the commonest species. It occurs throughout California and into Oregon. It varies much in appearance according to the location in which it grows, these variations being so striking that they have been considered different species, and perhaps two species ought to be admitted. It is perennial, with erect culms usually from 1 to 3 feet high, and a spike-like panicle varying from 3 to 6 inches in length and more or less interrupted or lobed at the lower part. When grown in very arid places the culms may be only a foot high, the radical leaves short, and the panicle only 2 inches long. When grown in more favored situations the radical leaves are 18 inches long, the stem 3 feet, and the panicle 6 inches long. The branches of the panicle are, in short, nearly sessile clusters, crowded above, looser and interrupted below. The spikelets are from two to four flowered. The outer glumes are a little shorter than the spikelets, lanceolate, acute, compressed. The flowering glumes are similar, membranaceous, acute, or mucronate. The palet is of nearly equal length, thinner and two-toothed at the apex. The flowers, panicle, culm, and leaves are usually more or less softly hairy. It is readily eaten by cattle. (Plate 88.)

ERAGROSTIS.

Of this genus we have about twenty species in the United States. It is characterized as follows: Spikelets numerous, usually in a loose, sometimes spreading and diffuse, panicle; commonly many flowered (rarely two or three only), sessile or pediceled, usually glabrous; the outer glumes are unequal and rather shorter than the flowering ones, keeled and mostly one-nerved; the flowering glumes are membranaceous, acute or obtuse, unawned, but rarely mucronate pointed, three-nerved, the keel prominent, the lateral nerves sometimes very faint; the palet shorter than its glume, with two prominent nerves or keels, often persisting after the glume and grain have fallen away.

ERAGROSTIS POÆOIDES var. MEGASTACHYA. (Pungent meadow grass.)

This is a foreign grass which has become extensively naturalized, not only in the older States but in many places in the western and southwestern Territories. It is found in waste and cultivated grounds and on roadsides, growing in thick tufts, which spread out over the ground by means of the geniculate and decumbent culms. The culms are from 1 to 2 feet long, the lower joints bent and giving rise to long branches. The sheaths are shorter than the internodes, the leaves from 3 to 6 inches long. The panicle is frequently 4 or 5 inches long, oblong or pyramidal, somewhat open, but full-flowered; the branches irregularly single or in pairs, branched and flowering nearly to the base. The spikelets are oblong or lanceolate one-fourth to one-half inch long, and ten to twenty flowered when well developed. The empty glumes are smaller than the flowering ones, rough on the keel, acutish. The flowering glumes are one line long, ovate, rather obtuse, and strongly three-nerved. The palets are shorter than their glumes, narrow, the sides reflexed and the margin ciliate. This grass is said to have a disagreeable odor when fresh. It produces an abundance of foliage, and is apparently an annual, reaching maturity late in the season. We are not aware that its agricultural value has been tested. (Plate 89.)

ERAGROSTIS PURSHII.

This is a native grass, very widely diffused over the United States, and extends into Mexico. In habit it is somewhat like the preceding species (*E. poœoides*), growing in tufts, with the culms branching at the base and the lower joints bent. The culms are smooth, slender, 10 to 20 inches high, the leaves narrow and sparse, with a tendency to produce an abundance of flowering culms. The panicle is oblong, open and spreading, 3 to 4 inches long, with the branches irregularly single or in pairs, and much subdivided. The spikelets are oblong, lanceolate to linear, about two lines long, and usually from five to fifteen flowered. The empty glumes are small, only about half the length of the flowering glumes, ovate and acute. The flowering glumes are about half a line

long, acutish, and distinctly three-nerved. It has little or no agricultural value except in arid, sandy districts, where it seems to be most common. (Plate 90.)

MELICA.

Of this genus we have ten to twelve species. Its characters are as follows: Spikelets two to many flowered; the flowers usually convolute around each other, the upper one smaller and imperfect; the outer glumes membranaceous or hyaline, acute or obtuse, awnless, the lower one three to five and the upper sometimes seven to nine nerved, the lateral nerves not reaching to the margin. The flowering glumes are of thicker texture, becoming coriaceous, scarious at the apex, rounded or flattish on the back, five to nine nerved, the lateral nerves not reaching the apex, the central one sometimes ending in a point or an awn; the palets shorter than their glumes, two-keeled, ciliate on the keels.

MELICA MUTICA. (Melic grass.)

A perennial grass, growing sparingly in rich, rocky woods throughout most of the States east of the Rocky Mountains. It grows in loose tufts, the culms about 2 feet high, the lower leaves and sheathes soft hairy, the upper leaves narrow, 3 to 4 inches long, gradually pointed. The panicle is very simple or little branched. In the variety *diffusa* the panicle is larger, more branched and spreading; the spikelets are loosely arranged on the branches, almost sessile, and rather on one side of the branches. They are large and graceful in appearance, each one consisting of two perfect flowers and a small chaffy knob, called a rudiment. The outer glumes are thin, scarious-margined, five to seven nerved, purplish, and three to four lines long. The flowering glumes are thicker, strongly ribbed, scarious at the blunt apex, and minutely rough on the nerves. The two flowers are somewhat distant from each other. The palets are narrower and shorter than the flowering glumes, arched and ciliate on the keels. This grass is eaten and relished by cattle, but is probably not well adapted to cultivation. (Plate 91.)

MELICA BULBOSA. (Bulbous Melic grass.)

This species is distinguished by its large bulbous roots, or, more properly, by the bulb-like enlargement of the base of the culm. It grows to the height of 2 or 3 feet; the leaves narrow, scabrous, and mostly involute. The panicle is from 4 to 8 inches long, narrow, with short and distinct branches, which are mostly in pairs, erect and densely flowered. The spikelets are about half an inch long, with usually three or four flowers, the upper one sterile. The outer glumes are thin, broad, and obtuse, the lower one three to five nerved, the upper five to seven nerved. The flowering glume is about a quarter of an inch long, obtuse, roughish, and seven-nerved. The palet shorter than the flower-

glume and ciliate on the keels. This species grows in the mountain ion of California and Oregon, also in Nevada. Utah, and Wyoming. ate 92.)

LICA IMPERFECTA.

There are seven or eight species of *Melica* in California, some of them te common, but they do not appear to have much agricultural value. e *Melica imperfecta* grows in tufts in shaded ground. There are sev- l varieties, which differ considerably in size and general appearance. ey may be described in general terms as growing from 1 to 3 feet h, with slender, rather wiry culms; the lower leaves are narrow, h long-tapering points, and about half as long as the culm, generally oth or slightly scabrous. The roots are perennial, with strong fibers. e panicle varies in the different varieties from 6 to 12 inches in length, her narrow, with distant rays, which are very unequal in length, and clusters from three to five. The longer rays are 1 or 2, or sometimes nches long, flower-bearing for half or two-thirds their length, while shorter ones, ½ to 1 inch long, are flower-bearing to their base. The kelets are one-quarter of an inch or less in length, and usually with flowers, one of which is imperfect, sometimes, however, with three wers, one or two of which are imperfect. The outer glumes are fre- ntly purplish, with thin, whitish margins, slightly obtuse, and three five nerved. The flowering glume is about seven-nerved, usually rplish, rather acute; the palet of about the same length and two- thed. The imperfect flower has a short pedicel, and is about half long as the perfect one. (Plate 93.)

UNIOLA.

This genus has closely, many-flowered spikelets, usually large, very lat, and two-edged, one or more of the lowest flowers neutral and con- isting only of an empty glume; the glumes are closely folded together, keeled, rigid, or coriaceous; the flowering ones larger, many-nerved, usually acute or pointed, entire; palet rigid, two-keeled, the keels nar- owly winged.

UNIOLA LATIFOLIA. (Broad-flowered Fescue grass.)

This is a handsome grass, growing 2 to 3 feet high, with very broad leaves and a spreading panicle; the drooping spikelets larger than those of any other grass we have, being an inch long or more, and nearly half as wide, consisting of ten to twelve flowers. It grows from Pennsyl- vania and Illinois southward. Mr. Charles Mohr, Mobile, Ala., says of this grass:

A fine vernal grass, with a rich foliage, blooming early in May; 2 to 3 feet high; frequent in damp, sandy loam, forming large tufts. This perennial grass is certainly valuable, affording an abundant range early in the season; if cultivated it would yield large crops ready for cutting from the 1st of May. It is called by some *wild*

fescue or *oat grass*. It is not found near the coast, consequently I had no chance to observe its growth during the latter part of the summer and in the winter season, and therefore am not able to judge of its value as a pasture grass.

(Plate 94.)

DISTICHLIS MARITIMA. (Salt grass, Marsh grass.)

This is described in most botanical works as *Brizopyrum spicatum*, but recently the name given by Rafinesque has been accepted and restored to it by Mr. Bentham. It is a perennial grass, growing in marshes near the sea-coast on both sides of the continent, and also abundantly in alkaline soil throughout the arid districts of the Rocky Mountains. It has strong, creeping root-stocks, covered with imbricated leaf-sheaths, sending up culms from 6 to 18 inches high, which are clothed nearly to the top with the numerous, sometimes crowded, two-ranked leaves. The leaves are generally rigid and involute, sharp-pointed, varying greatly in length on different specimens. The plants are diœcious, some being entirely male and some female. The panicle is generally short and spike-like, sometimes, especially in the males, rather loose, with longer, erect branches, and sometimes reduced to a few spikelets. The spikelets are from four to six lines long and five to ten flowered, the flowers being usually much compressed. The outer glumes are smooth, narrow, and keeled; the flowering ones are broader, keeled, acute, rather rigid, and faintly many-nerved. The palets have an infolded margin, the keels prominent or narrowly winged. The pistillate spikelets are more condensed and more rigid than the staminate. Although this cannot be considered a first-rate grass for agricultural purposes, it is freely cut with other marsh grasses, and on the alkaline plains of the Rocky Mountains it affords an inferior pasturage. (Plate 95.)

DACTYLIS GLOMERATA. (Orchard grass, Cocksfoot grass.)

This is one of the most popular meadow grasses of Europe, and is well known to most farmers in the Northern and Eastern States. It is a perennial, of strong, rank growth, about 3 feet high, the culm and leaves roughish, the leaves broadly linear, light green, and five to six on the culm. The panicle is generally but 2 or 3 inches long, the upper part dense from the shortness of the branches; the lower branches are longer and spreading, but with the spikelets glomerated or closely tufted. The spikelets are usually three to four flowered, one-sided, and on short, rough pedicels. The glumes are pointed and somewhat unequal, the upper one being smaller and thinner than the lower. The flowering glumes are ovate-lanceolate, roughish, and ending in a sharp point or short awn, and are rather longer than the outer glumes.

Professor Phares, of Mississippi, says:

Of all grasses this is one of the most widely diffused, growing in Africa, Asia, every country of Europe, and all our States. It is more highly esteemed and commended than any other grass by a larger number of farmers in most countries, a most decided

proof of its great value and wonderful adaptation to many soils, climates, and treatments. Yet, strange to say, though growing in England for many centuries, it was not appreciated in that country till carried there from Virginia in 1764. But, as in the case of timothy grass, soon after its introduction from America, it came into high favor among farmers, and still retains its hold on their estimation as a grazing and hay crop. It will grow well on any soil containing sufficient clay and not holding too much water. If the land be too tenacious, drainage will remedy the soil; if worn out, a top dressing of stable manure will give it a good send-off, and it will furnish several mowings the first year. It grows well between 29° and 48° latitude. It may be mowed from two to four times a year, according to latitude, season, and treatment, yielding from 1 to 3 tons of excellent hay per acre on poor to medium land. It is easily cured and handled. It is readily seeded and catches with certainty. It grows well in open lands and in forests of large trees, the underbrush being all cleared off. I know but one objection to it. Like tall oat grass it is disposed to grow in clumps and leave much of the ground uncovered. This may be obviated by thick seeding, using 2½, or, better, 3 bushels of seed per acre. The gaps may be prevented by sowing with it a few pounds of red-top seed. But as the latter multiplies annually from seeds dropping, it would in a few years root out the orchard grass. In common with others I prefer red clover with orchard grass. It fills the gaps and matures at the same time with the orchard grass; the mixture makes good pasture and good hay; but if mowed more than twice a year, or grazed too soon after the second mowing, the clover will rapidly fail. One peck of red clover seed and six pecks of orchard grass seed is a good proportion per acre. * * * After being cut it has been found to grow inches in less than three days. Sheep leave all other grasses if they can find this, and acre for acre it will sustain twice as many sheep or other stock as timothy. Cut at the proper stage it makes a much better hay than timothy, and is greatly preferred by animals, being easier to masticate, digest, and assimilate; in fact, more like green grass in flavor, tenderness, and solubility.

Mr. J. S. Gould, of New York, says:

The testimony that has been collected from all parts of the world for two centuries past establishes the place of this species among the very best of our forage grasses, and we have not the shadow of a doubt that the interests of our graziers and dairymen would be greatly promoted by its more extended cultivation. It is always found in the rich old pastures of England, where an acre of land can be relied on to fatten a bullock and four sheep. It is admirably adapted for growing in the shade, no grass being equal to it in this respect, except the rough-stalked meadow grass (*Poa trivialis*). It receives the name of orchard grass from this circumstance. We have seen it growing in great luxuriance in dense old New England orchards, where no other grass except *Poa trivialis* would grow at all. It affords a good bite earlier in the spring than any other grass except the meadow fox-tail (*Alopecurus pratensis*). It affords a very great amount of aftermath, being exceeded in this respect by no other grass except Kentucky blue grass (*Poa pratensis*), and it continues to send out root leaves until very late in the autumn. When sown with other grasses its tendency to form tussocks is very much diminished; indeed, it is always unprofitable to sow it alone in meadows or pastures, as it stands too thin upon the ground to make a profitable use of the land, and the filling up of the interspaces with other varieties greatly improves the quality of the orchard grass by restraining its rankness and making it more delicate.

Mr. Sinclair states, and the statement has been abundantly verified in all countries, that the herbage when suffered to grow rank or old contains one-half less nutriment than that which is of recent growth. Cattle, sheep, and horses eat it with the greatest avidity when it is young, but will not touch it when old, hence the importance, when

pastures have been understocked, of going over them with a mowing machine; the orchard grass will then stool out, and the cattle will be found eating first on the very spots that they had previously rejected. (Plate 96.)

POA.

This is an extensive genus, there being about thirty-five species in the United States, and it contains some of the most valuable grasses for pasturage.

The chief characters of the genus are as follows: Spikelets somewhat compressed, usually two to five flowered; the axis between the flowers glabrous, or sometimes hairy; the flowers generally perfect, in a few species diœcious; the outer glumes commonly shorter than the flowers, membranaceous, keeled, obtuse or acute, one to three nerved, not awned; the flowering glumes membranaceous, five or rarely seven nerved; the lateral nerves frequently very faint and obscure, often scarious at the apex and margins; the back, especially toward the base, frequently pubescent on the nerves, often with a few or many loose or webby hairs at the base; palet about as long as its glume, prominently two-nerved or two-keeled.

POA PRATENSIS. (June grass, Kentucky blue grass, Spear grass.)

This grass is too well known to need an extended description. It is a perennial, growing usually 1½ to 2 feet high, with an abundance of long, soft, radical leaves. There are several well-marked varieties, which are much modified and improved by good cultivation. It is indigenous in the mountainous regions of this country as well as of Europe, and has been introduced into cultivation in many countries. The panicle is generally pyramidal in outline, 2 to 4 inches long, open and spreading, the branches fine, mostly in fives, the lower ones 1 to 3 inches long, subdivided and flowering above the middle. The spikelets are about two lines long, ovate, closely three to five flowered, mostly on very short pedicels. The outer glumes are acute; the flowering glumes acute or acutish, five-nerved, the lateral nerves prominent, the lower part of the keel and marginal nerves more or less hairy, and at the base more or less webby-hairy. From the unexampled success its cultivation has met with in Kentucky it has acquired the name of Kentucky blue grass, although in New England it is known by the name of June grass. In all the middle portions of the United States it forms the principal constituent of pastures, though its excellence is said to be rather depreciated in the Eastern States.

In some sections it has been used as a hay grass, but it is not a success as a meadow, its chief excellence being exhibited as a pasture grass. It endures the frosts of winter better than any other grass we have, and if allowed to grow rank during the fall months it will turn over and hide beneath its covering the most luxuriant of winter croppings.

Professor Killebrew, of Tennessee, says:

It would seem a work of supererogation to argue as to the advantages of cultivating this grass. All know its benefits, and all see around them the great increase in the value of the land covered by it. It grows readily in all parts of the United States north of 40°, and lower down on suitable soils. It flowers in the earliest summer, and gives rich pasturage, except in the driest months, all the year. It varies in size in different localities according to soil and climate.

Professor Phares, of Mississippi, says:

Kentucky blue grass, known also in the Eastern States as June grass, although esteemed in some parts of America as the best of all pasture grasses, seems not to be considered very valuable among English farmers except in mixtures. It is certainly a very desirable grass, however. Its very narrow leaves, 1, 2, or more feet long, are in such profusion and cover the ground to such depth with their luxuriant growth that a mere description could give no one an adequate idea of its beauty, quantity, or value; that is, on rich land. On poor, sandy land it degenerates sadly, as do other things uncongenially located. Perennial, and bearing cold and drought well, it furnishes grazing a large part of the year. It is specially valuable as a winter and spring grass for the South. In prolonged summer drought it dries completely, so that if fired it would burn off clean. But this occurs even in Kentucky, where, indeed, it has seemed, without fire, to disappear utterly; yet when rain came, the bright green spears promptly recarpeted the earth. Sown alone, 20 to 26 pounds, that is 2 bushels, should be used to the acre; in mixtures, 4 to 6 pounds.

Mr. Klippart, of Ohio, says that this grass is very much in favor in Southern Ohio, whilst in Northern and Northeastern Ohio it is considered a very unwelcome guest in the grass lands. This difference of estimation is probably due to varieties, or to alteration of soil and to treatment. (Plate 97).

POA TRIVIALIS. (Rough-stalked Meadow grass.)

This species very much resembles the *Poa pratensis*. It is distinguished chiefly by its having rough sheaths, by its long, pointed ligules, its fibrous roots, and the smooth marginal nerves of the flowering glumes; whereas, in *Poa pratensis*, the sheaths are smooth, the ligules obtuse, the root-stock running, and the marginal nerves of the flowering glumes are hairy. It has been little cultivated by itself in this country, but is sometimes found in low meadows or on the banks of shaded streams. It flourishes best in low or wet ground and in shaded situations, and is not so well adapted to general cultivation as the blue grass.

Professor Phares, of Mississippi, says:

It is specially adapted to wood pastures, as it delights in shade, banks of streams, and moist ground generally. It bears tramping and is an excellent pasture grass. It makes a good mixture with red top and orchard grass, or red top and tall oat grass, and with other pasture grasses.

POA SEROTINA. (Fowl Meadow grass.)

Culms erect, 2 to 3 feet high, without running root-stocks. The leaves are narrowly linear, 3 to 6 inches long and two to three lines wide, the sheaths long, smooth, and striate, the ligules long. The panicle varies

with the size of the plant from 5 to 10 or 12 inches long and 1 to 3 inches wide, and lax; the branches mostly in fives or more numerous, nearly erect, from 1 to 4 inches long, the longer ones subdivided and flowering above the middle. There are some mountain forms or varieties in which the culms are 1 foot or less in height and the panicle greatly reduced. The spikelets are one to two lines long, two to five flowered, on short pedicels. The outer glumes are about one line long and sharp-pointed. The flowering glumes are rather obtuse, the lateral nerves not prominent, slightly pubescent on the margins below, and somewhat webby at the base.

This species is most common in the Northern States, particularly in New England, New York, and westward to Wiscousin, and also in reduced forms in all mountainous districts.

Mr. J. S. Gould, of New York, says:

I have found it to grow on almost every kind of soil; but it attains the greatest perfection in a rich moist one. It is one of those grasses that thrive best when combined with others; it will not make a superior turf of itself, but it adds much to the value of a sward from its nutritive qualities and powers of early and late growth. As it perfects an abundance of seed it may be easily propagated.

Professor Phares, of Mississippi, says:

In portions of the Western States this grass has, for some years, been very highly recommended. In the Eastern States it has been cultivated for one hundred and fifty years or longer and valued highly. Jared Elliott, in 1749, spoke of it as growing tall and thick, making a more soft and pliable hay than timothy and better adapted for pressing and shipping for use of horses on shipboard. He says it makes a thick, abundant growth on land more moist than is adapted to common upland grasses, and may be mowed any time from June to October, as it never becomes so coarse and hard but the stalk is sweet and tender and eaten without waste. It has not been sufficiently cultivated in the Southern States, so far as I am aware, to know how long a meadow set with it may remain profitable. It is, however, worthy of extended trial.

Mr. Charles L. Flint says:

It grows abundantly in almost every part of New England, especially where it has been introduced and cultivated in suitable ground, such as the borders of rivers and intervals occasionally flooded. It never grows so coarse or hard but that the stalk is sweet and tender, and eaten without waste. It is easily made into hay, and is a nutritive and valuable grass.

(Plate 98.)

POA COMPRESSA.. (Wire grass, Blue grass.)

This species has sometimes been confounded with the Kentucky blue grass, from which it differs in its flattened, decumbent, wiry stems, its shorter leaves and shorter, narrower, and more scanty panicle. It is found in many old pastures, on dry banks, and in open woods. The culms are hard and much flattened, 1 foot to 18 inches long, more or less decumbent, and frequently bent at the lower joints. The leaves are scanty, smooth, short, and of a dark bluish-green color. The pani-

cle is short and contracted, 1 to 3 inches long. The branches are in pairs or threes, short, rough, and frequently one sided. The spikelets are ovate-oblong, flat, short-stalked, and generally three to five flowered. The outer glumes are acute, the flowering ones obtuse, smooth, the nerves obscure, and the apex frequently purplish colored. It forms a very firm turf by means of its creeping rootstalks. Very contradictory accounts have been given as to its agricultural value, some denouncing it as worthless and others entertaining a good opinion of it. It thrives well on clay, or hard trodden and poor soils.

Hon. J. S. Gould says, respecting it:

It is certain that cows that feed upon it both in pasture and in hay give more milk and keep in better condition than when fed on any other grass. Horses fed on this hay will do as well as when fed on timothy hay and oats combined.

These discrepant opinions may be due in part to having mistaken the *Poa pratensis* for this grass. It is probably a nutritious grass, but from its spare yield can hardly obtain much favor for a hay crop. (Plate 99.)

POA ARACHNIFERA. (Texas Blue grass.)

This species was first described by Dr. John Torrey in the report of Captain Marcy's exploration of the Red River of Louisiana, as having been found on the headwaters of the Trinity, and named *Poa arachnifera* from the profuse webby hairs growing about the flowers, although it is found that this character is very variable, probably depending somewhat on the amount of shade or exposure to which the grass is subject.

Several years ago Mr. Hogan, of Texas, sent specimens of the grass to this Department, and as it was shown to be a relative of the Kentucky blue grass, Mr. Hogan adopted for the common name Texas blue grass. We give some extracts from his letters relating to the grass:

I find it is spreading rapidly over the country, and I claim for it all and more in Texas than is awarded to the *Poa pratensis* in Kentucky. It seems to be indigenous to all the prairie country between the Trinity River and the Brazos in our State. It blooms here about the last of March, and ripens its seeds by the 15th of April. Stock of all kinds, and even poultry, seem to prefer it to wheat, rye, or anything else grown in winter. It seems to have all the characteristics of *Poa pratensis*, only it is much larger, and therefore affords more grazing. I have known it to grow 10 inches in ten days during the winter. The coldest winters do not even nip it, and although it seems to die down during summer it springs up as soon as the first rains fall in September and grows all winter. I have known it in cultivation some five years, and have never been able to find a fault in it. It will be ready for pasture in three or four weeks after the first rains in the latter part of August or first of September. I have never cut it for hay. Why should a man want hay when he can have green grass to feed his stock on?

Mr. James E. Webb, of Greensborough, Hale County, Alabama, writes to the Department December 26, 1883, and says:

Recent experiments show that the Texas blue grass (*Poa arachnifera*) flourishes and grows here in west Alabama as finely as could be wished, and is likely ere long to furnish us what we so much need, a fine winter grass. With Texas blue grass, Melilotus, and Bermuda grass, Alabama is a fine stock country.

Mr. S. C. Tally, of Ellis County, Texas, has sent specimens of this grass; he says it is abundant there, bears heavy pasturing, and makes a beautiful yard or lawn grass.

Similar favorable accounts have been received from others. It is likely to prove one of the most valuable grasses for the South and Southwest. By means of its strong stolons or offshoots it multiplies rapidly and makes a dense permanent sod. It produces an abundance of radical leaves, and those of the culm are long, smooth, and of good width, about 4 to 8 inches long and two lines wide. The culms are 2 to 3 feet high, each with two or three leaves, with long sheaths and blade, the upper leaf sometimes reaching nearly to the top of the panicle. The ligule is short and rounded, or lacerated when old. The panicle is from 3 to 8 inches in length, rather narrow, and with short, erect branches of unequal length, in clusters of from three to five, the longest seldom 2 inches, most of them short, some nearly sessile, and profusely flowering to the base. The spikelets usually contain about five flowers. The outer glumes are ovate-lanceolate, acute, with whitish scarious margins, and scabrous on the keel. The flowering glumes are longer, gradually sharp pointed, and smooth except on the margins and midnerve, which are usually pubescent, sometimes densely so. In many cases there is a remarkable development of long, silky hairs at the base of each flower, but sometimes these are quite absent. (Plate 100.)

POA TENUIFOLIA. (Oregon Blue grass.)

There is some uncertainty about the proper specific name of this grass. In the report for 1881–'82 it was published as *Poa Californica*, but it seems probable that that name belongs to a different species. It is common in California, Oregon, and Washington Territory, and is one of the numerous bunch grasses referred to in accounts of the wild pasturage of that country. The foliage of some forms of the grass seems to be too scanty, but of others the radical leaves are long and abundant. It furnishes an abundance of nutritious seeds, which are said to be gathered for food by Indians.

The culms are from 1½ to 3 feet high, erect, and scantily clothed with a few short, narrow leaves. The panicle is erect, 3 to 5 inches long, rather narrow and loose, the branches mostly in fives, unequal, from ½ to 1½ inches long, flowering above the middle. The spikelets are three to five flowered; the outer glumes are oblong-lanceolate, about two lines long, nearly as long as the flowers, three-nerved, rough on the keel, somewhat scabrous, and acutish. The flowering glumes are lanceolate, convex, or slightly compressed toward the apex, indistinctly five-nerved, two to three lines long, acutish, minutely scabrous, the apex and margins scarious and of a bronze or purplish color, sometimes slightly pubescent near the base. The palet is almost as long as its glume, narrower and bidentate at the apex.

It is probable that this species, by careful cultivation, may be made as valuable in agriculture for the region where it grows as the *Poa pratensis* is in the Eastern States. (Plate 101.)

POA ALSODES. (Tall Spear-grass, Woods grass, Wood Spear grass.)

A species of spear-grass of, probably, no great agricultural value, but found in mountainous districts in the northern parts of the United States, in woods and on hill sides in New England, New York, the mountainous parts of Pennsylvania, and westward to Wisconsin. The culms are 2 to 2½ feet high, slender, erect, and with about three narrowly-linear leaves, each 3 to 4 inches long. The panicle is about 6 inches long, very open, and composed of about four whorls of branches, chiefly in fours, the lower ones distant, very slender, 2 to 3 inches long, and with few flowers only toward the extremity of the branches. The species may most readily be distinguished by the acute flowers. The spikelets are about two lines long, chiefly three-flowered. All the glumes are acutely-pointed, the flowering ones obscurely nerved, and with a narrow tuft of long, webby hairs at the base.

Mr. J. S. Gould says:

It flourishes on mountain sides from 1,000 to 3,000 feet above the sea, but is very well adapted for lawns and for thick, shady places, where few other kinds will grow. The seeds weigh about 15 pounds to the bushel.

(Plafe 102.)

POA ANDINA OF NUTTALL. (Mountain Spear grass.)

A perennial tufted grass, with short, narrow, rigid, and pungently pointed leaves, usually involute; the culms are 6 to 18 inches high, smooth, or nearly so, wiry and naked, except about two very short leaves, the blade an inch long, or almost wanting. The panicle is 2 to 4 inches long, narrow, erect, and rather loose, the branches mostly in pairs, which are erect, about an inch long, and flowering for the upper two-thirds, or nearly throughout. The spikelets are three to five flowered, and nearly sessile; the outer glumes are one and a half lines long, nearly equal, thin, ovate-lanceolate, acute or acutish, the margins scarious, the lower one-nerved, and the upper obscurely three-nerved, minutely scabrous; the flowering glumes are oblong, obtuse, or obtusish, slightly compressed, rounded on the back, at least below, obscurely nerved, softly and finely pubescent and below villous; the apex scarious and tinged with purple, sometimes denticulate or lacerated; the palets are as long as their glumes, and pubescent on the nerves. The flowers separate very readily and drop off early.

This grass prevails widely throughout the region of the great plains and table lands from Arizona to British America. Little is known of its agricultural value. (Plate 103.)

POA ANNUA. (Annual Spear grass, Goose grass.)

This grass is a native of Europe, but has become extensively naturalized in this and many other countries. It is an annual or biennial species of low growth, usually 3 or 4 to 6 or 10 inches high, with pale-green, tender leaves. It is commonly found in door-yards or neglected lots or on the roadside. It blooms very early in the spring, and also frequently in the fall. It is very nutritious, but so small that the yield is deficient in quantity. It appears to die at the approach of hot weather.

Poa flexuosa, *Poa brevifolia*, *Poa debilis*, and *Poa sylvestris*, are species growing in woods or shaded grounds in different parts of the country, South and East, but are not of much agricultural importance.

GLYCERIA.

This genus is closely related to *Poa*, and is characterized as follows: Spikelets terete or flattish, several to many flowered, the axis of the flowers smooth, the outer glumes shorter than the flowers, unequal, membranaceous, one to three nerved, the flowering glumes membranaceous or subcoriaceous, obtuse, awnless, more or less hyaline, and finely-toothed or worn at the apex, rounded (not keeled) on the back, five to nine nerved, the nerves separate and all vanishing before reaching the apex; palet about as long as its glume, two-keeled, entire or bifid at the apex.

The species of this genus are not of much agricultural importance. They mostly grow in wet or swampy ground, and where found in abundance can be utilized for pasturage or hay-making.

GLYCERIA AQUATICA. (Reed Meadow grass, White Spear grass.)

This species is widely diffused in the northern portions of the United States, Canada, the Rocky Mountains, and the Northwestern States and Territories. It has a stout, erect, leafy culm, 3 to 4 feet high. The leaves are a foot or two long, a quarter to half an inch wide, flat, and somewhat rough, especially on the edges. The panicle is large, 9 to 15 inches long, much branched; the branches arranged in half whorls alternately on the main axis, at first erect, but spreading with age. The spikelets are oblong, about three lines long, five to nine flowered, on capillary pedicels. The lower third of the branches is naked. The outer glumes are one-nerved, and unequal. The flowering glumes are obtuse, prominently seven nerved or ribbed, mostly entire at the apex. The palet is two-toothed, two-nerved, and about as long as its glume.

Hon. J. S. Gould says:

> This grass is made into hay which is liked by cattle. It flowers in July. It is found in most parts of Europe, and is widely diffused in this country in wettish meadows.

It is doubtful if the European grass of this name is identical with the American one, although much resembling it. (Plate 104.)

GLYCERIA NERVATA. (Nerved Meadow grass, Nerved Manna grass.)

This is similar in appearance and habit to the preceding, but generally smaller. It has also much the same general range. The culms are 2 to 3 feet high, usually somewhat decumbent below, often branching and rooting at the lower joints. It varies greatly in size and in the magnitude of the panicle. It usually grows along the wet margins of streams and in swamps. The panicle is from 4 to 8 inches long, nodding when young, loose and spreading, with capillary branches. The leaves are 8 to 12 inches long, and two to three lines wide. The spikelets are small, about five-flowered, oblong, frequently becoming purplish with age. The outer glumes are unequal, obtuse, thin, and small, neither of them much more than half as long as the flowers. The flowering glumes are obtuse, oblong, prominently five to seven ribbed, and entire or minutely ciliate at the apex. The palet is as long as its glumes, two-nerved, two-toothed at the apex. Like the preceding this grows in wet meadows and swamps. It is nutritious and might be advantageously mixed with other grasses in wet or swampy grounds.

Mr. Charles L. Flint says:

It is a hardy grass, grows best on moist ground, but is said to succeed also on lightish upland soils. It is a very valuable native grass, retaining its nutritive qualities until the seed is ripe, and then sending up large fan-like shoots which are succulent and nutritious. It would be a valuable ingredient in a mixture for wet or moist pastures.

(Plate 105.)

GLYCERIA CANADENSIS. (Rattlesnake grass, Tall quaking grass.)

A grass belonging to the northern portion of the United States, usually found in mountainous districts, in swamps, and river borders, growing in clumps. The culms are stout, about 3 feet high, smooth and leafy. The leaves are linear-lanceolate, 6 to 9 inches long, or the lower ones much longer, about four lines broad and rather rigid. The panicle is large and effuse, 6 to 9 inches long, oblong pyramidal, and at length drooping. The whorls are an inch or more distant, the branches semi-verticillate, mostly in threes, the largest 3 to 4 inches long, and subdivided from near the base. The spikelets are oblong to ovate, when mature nearly three lines long, rather turgid, but flattened at the sides, usually six to eight flowered. The empty glumes are shorter than the flowering glumes, ovate-lanceolate, acute, purplish, the upper one largest. The flowering glumes are broadly ovate, acute, five to seven nerved, one and one-half to two lines long. The palets are shorter than their glumes and thicker in texture, roundish, and obtuse, with the sides strongly reflexed.

This is quite an ornamental grass, resembling the quaking grass (*Briza*). Cattle are fond of it, both green and when made into hay. It is well adapted to low meadows.

Hon. J. S. Gould says:

It is usually found on high elevations, in swampy lands, and by the margins of streams. It is very apt to grow in clumps. It is one of the most beautiful of grasses, and is exceedingly ornamental in grass boquets. It is abundant on the Catskill and White Mountains and on the Raquette waters of the Adirondacks. Cattle eat it very well in pasture and when made into hay.

(Plate 106.)

GLYCERIA FLUITANS. (Floating Manna grass.)

This species grows in shallow water on the margins of lakes, ponds, and sluggish streams. Its culms are usually 3 to 4 feet high, rather thick and succulent and quite leafy. The leaves are 4 to 9 inches long and three to four lines wide. The panicle is often a foot long, very narrow, the short distant branches mostly in twos or threes, 1 or 2 inches long, erect and close, each having usually two to four spikelets. The spikelets are half an inch to three-quarters of an inch in length, rather cylindrical and nearly of the same thickness throughout, seven to thirteen flowered. The outer glumes are membranaceous and one-nerved. The flowering glumes are about two lines long, oblong, convex on the roughish back, rather thick, with a thin, scarious entire apex. The palets are as long or sometimes longer than their glumes and minutely two-toothed.

Hon. J. S. Gould says:

This grass is found growing in shallow water, overflowed meadows and wet woods, but will bear cultivation on moderately dry grounds. Schreber says that it is cultivated in several parts of Germany for the sake of the seeds, which form the manna crop of the shops, and are considered a great delicacy in soups and gruels. When ground into meal they make bread very little inferior to that made from wheat. In Poland large quantities of the seeds are obtained for culinary purposes. All granivorous birds are exceedingly fond of these seeds. Trout and indeed most fish are very fond of them; wherever it grows over the banks of streams the trout are always found in great numbers waiting to catch every seed that falls. There is a great difference of opinion among agricultural writers with respect to the fondness of animals for the leaves and culms of this grass. We have often seen the ends of the leaves cropped by cattle, but have never seen the culms or root-leaves touched by them. On the other hand, reliable writers have asserted that cattle, horses, and swine were alike fond of it.

FESTUCA.

This is a large genus, of which we have some fifteen native and several introduced species. The genus is characterized as follows: Spikelets, three to many flowered, variously panicled, pedicellate; axis of the spikelets not hairy, outer glumes unequal, shorter than the flowers, the lower one-nerved and the upper three-nerved, narrow, keeled, acute; flowering glumes membranaceous, chartaceous, or subcoriaceous, narrow, rounded on the back (not keeled), more or less distinctly three to five nerved, acute, or commonly tapering into a straight awn, rarely obtusish; palet narrow, flat, prominently two-nerved or two-keeled.

FESTUCA ELATIOR. (Meadow Fescue grass, Tall Fescue, Randall grass, Evergreen grass.)

A perennial grass, growing from 2 to 4 feet high, with flat, broadish leaves about a foot long. The panicle is somewhat one-sided, loose, and spreading when in flower, contracted after flowering, from 6 to 10 inches long, the branches 1 to 2 inches long, erect, mostly in pairs below, single above, subdivided; the spikelets are lanceolate or linear, about half an inch long, five to ten flowered. The outer glumes are one and three nerved, shorter than the flowers; the flowering glumes are lanceolate, about three lines long, firm in texture, five-nerved, scarious at the margin, acute, and sometimes with a short but distinct awn at the apex. This is an introduced species, now frequently met with in meadows; it is one of the standard meadow grasses of Europe. Cattle are said to be very fond of it, both green and as hay. There is a smaller form or variety which is the variety *pratensis* or *Festuca pratensis, Hudson.*

Professor Killebrew, of Tennessee, writes of this grass as follows:

This grass has received some attention in different parts of the State, and has met with a warm reception from those testing it. It ripens its seed long before any other grass, and consequently affords a very early nip to cattle. It has been raised under various names, in Virginia as "Randall grass," and in North Carolina as "evergreen grass." Mr. James Taylor, writing from North Carolina, says: "The evergreen grass is very good for pasturing through the fall and winter. It will do best when sown on dry land, and is well adapted to sheep. It grows well on rocky soil to the height of 4 or 5 feet when ripe, continuing green in the spring, and affording fine herbage throughout the winter. It is best to sow in the spring with oats. A peck of well-cleaned seed is enough for an acre, or a bushel in the chaff. It ripens about the 1st of June. If sown in the spring this grass will not go to seed before the next year, but if sown in the fall it will bring seed the next spring." From the limited cultivation it has met with in Tennessee, it seems rather to be better adapted to moist, low lands, though I have seen it growing on some of the high ridges of East Tennessee, at least 1,500 feet above the sea. There it thrives luxuriantly and makes a very superior pasture.

Professor Phares, of Mississippi, says:

It grows well in nearly all situations, wet or dry, on hill or bottom land, even though subject to overflow, and matures an extraordinary quantity of seed. The seeds germinate readily, and it is easy to set a piece of land with this grass. Seeded alone, 28 pounds, or about 2 bushels, of seed should be sown broadcast in August, September, October, or from the middle of February to the 1st of April. From remaining green through the winter it is sometimes called "evergreen grass." Mowed and dried it makes a good hay, much relished by stock.

(Plate 107.)

FESTUCA OVINA. (Sheep's Fescue grass.)

A densely-tufted, perennial grass, with an abundance of rather narrow, sometimes involute, short radical leaves and slender culms, 1 to 1½ feet high. The panicle is 2 to 4 inches long, narrow, the branches mostly single and alternate, erect and few-flowered; the spikelets are

mostly three to five-flowered, and about three lines long; the outer glumes are acute and narrow. The flowering glumes are lanceolate, two lines long, roughish, and with a short rough awn about half a line long.

This species has many varieties, both in this country and in Europe. It is indigenous in the mountainous parts of New England, in the Rocky Mountains, and in various Northern localities.

As found in cultivation it has been derived from Europe.

Hon. J. Gould, of New York, says:

It forms the great bulk of the sheep pastures of the highlands of Scotland, where it is the favorite food of the sheep, and where the shepherds believe it to be more nutritious for their flocks than any other. Gmelin says that the Tartars choose to encamp during the summer where this grass is most abundant, because they believe that it affords the most wholesome food for all cattle, but especially for sheep. Nature distributes it among dry, sandy, and rocky soils, where scarcely any other species would grow. It is without doubt the very best of the grasses growing on sandy soils. It roots deeply, and forms a dense, short turf, which adapts it admirably for lawns and pleasure-grounds where the soil is sandy. It is almost useless as a hay crop, as its leaves and culms are too fine to give a remunerative amount of hay; it is only as a pasture grass on sandy soils that it is valuable, and in these, when highly manured, it is driven out by the more succulent species. It is often found 4,000 feet above the level of the sea. Its seeds weigh about 14 pounds to the bushel.

(Plate 108.)

FESTUCA MICROSTACHYS. (Small Fescue grass, Western Fescue.)

A slender annual grass, which is very common in California and Oregon, considerably like the small fescue (*Festuca tenella*). The culms are slender, 6 to 18 inches high; the leaves are short and narrow. The panicle is from 2 to 5 inches long, with rather distant short branches, which are mostly single at the joints, and apt to be one-sided, sometimes with the lower branches spreading or reflexed. The spikelets are small, from two to five flowered, on short, thickened pedicels, varying from smooth to pubescent. The outer glumes are acute, about a line long. The flowering glumes are two or three lines long, with an awn nearly twice as long; the palets have each two short, bristle-like teeth, which often project beyond the flowering glume. The grass is of little value, except as it helps to extend the pasturage of uncultivated ground. (Plate 109.)

FESTUCA SCABRELLA. (Bunch grass.)

A perennial grass, growing in strong clumps or bunches, and hence called "bunch grass." It is a native of the Rocky Mountain region, from Colorado westward to California and Oregon. The culms are usually 2 to 3 feet high, erect, and smooth; the radical leaves are numerous, about half as long as the culm, generally rigid, involute, and scabrous on the margins; the blade is prone to separate when old, leaving an abundance of leafless sheaths at the base; the cauline leaves are about two, short and pointed, 2 to 4 inches long; the sheath scabrous, the ligule short or wanting; the panicle is usually 3 to 5 inches long; the

rays spreading, 1 to 3 inches long, distant, usually in pairs below, single above, subdivided to the middle; spikelets five to six lines long, three to five flowered, the flowers rather distant; outer glumes ovate-lanceolate, membranaceous, acute or acuteish, obscurely nerved, the upper one two lines long, the lower one-third shorter; flowering glumes lanceolate, acute, or short cuspidate, about five-nerved, minutely scabrous, of thicker texture than the outer glumes; palet as long as its glume, two-nerved, bifid at the apex.

This grass varies greatly in size and appearance in different localities, one form in Oregon and California growing 3 to 5 feet high, with panicle twice as large as the mountain form. Cattle are said to be fond of it, and it is considered one of the most valuable wild grasses of the region where it grows. (Plate 110.)

BROMUS.

Spikelets five to many flowered, subterete or compressed, the axis smooth; the outer glumes more or less unequal, shorter than the flowers, membranaceous, acute, one to nine nerved, awnless or short mucronate; flowering glumes, membranaceous to rigid-subcoriaceous, rounded on the back, or compressed or keeled, five to nine nerved, acute or awned from below the mostly two-cleft apex; palet commonly rather shorter than its glume, two keels, the keels rigid and ciliate.

BROMUS SECALINUS. (Chess or Cheat.)

We introduce this grass, not to recommend its cultivation, but to familiarize those interested with its appearance and character. Many farmers know it well, as it occurs in their wheat fields. It is an old tradition, which some farmers still cling to, that chess is a degenerated wheat; that the action of frost and other causes occasion the deterioration, whereas the truth undoubtedly is that chess seed was either in the land or in the seed sown, and being more hardy than wheat it survived the frost and took possession of the ground. Some years ago this grass had a temporary popularity under the name of Willard's Brome grass, but it was soon abandoned when brought into competition with better grasses.

It has a stout upright culm, 2 to 3 feet high, the panicle being from 4 to 6 inches long, rather spreading, and the large spikelets somewhat drooping when ripe. Usually there are three to five branches at each joint of the panicle; these branches are of different lengths, from ½ inch to 2 inches, and each with one to three spikelets. The spikelets are usually from five to ten flowered; the glumes unequal, nerved, shorter than the flowers; the flowering glume is convex or compressed, keeled on the back, with an awn variable in length from below the point.

In the South it would perhaps be a good winter grass, like its relative *Bromus unioloides*, but it is not as vigorous a grass as that species, and does not produce such an abundance of foliage. (Plate 111.)

BROMUS UNIOLOIDES. (Schrader's grass, Rescue grass.)

This is one of the so-called winter grasses; that is, it makes in the South a large share of its growth during the winter months. It belongs to the chess or cheat family. In its early growth it spreads and produces a large amount of leaves; early in the spring it sends up its flower stalks, which grow about 3 feet high, with a large, open, spreading panicle, the ends of the branchlets bearing the large flattened spikelets, which, when mature, hang gracefully upon their stems, giving them quite an ornamental appearance. These spikelets are from 1 inch to 1½ inches in length, and composed of two acute lanceolate glumes at the base, and from seven to ten flowers arranged in two rows alternate on each side of the axis. The flowers are lanceolate, or ovate-lanceolate, the flowering glume extending into a fine point or short awn.

During several years past this grass has been sent to this Department, chiefly from Louisiana and Texas, and has been much commended. Many years since the same grass was distributed and experimented with under the name of Australian oats, or *Bromus Schraderi*. It is not adapted to use in a country with severe winters, and hence did not give satisfaction in all places. Mr. C. Mohr, of Mobile, says of it:

Only of late years found spreading in different parts of this State; makes its appearance in February, grows in tufts, its numerous leafy stems growing from 2 to 3 feet high; it ripens the seed in May; affords in the earlier months of spring a much-relished nutritious food, as well as a good hay.

Under date of March 4, 1878, Mr. Williams writes from San Antonio, Tex., describing the introduction and spreading of a patch of this grass. He says:

Inasmuch as Western Texas is the great stock-producing section of the Southwest, and considering the fact that pasturage is scanty, particularly in February, stunting the growth of young cattle, this seems wonderfully adapted to supply just what is greatly wanted, both for milch cows, calves, colts, and ewes just dropping their lambs; and besides, this grass grows well on the thinnest soil and crowds out weeds, maturing in March and early April, while not interfering with the native *mesquite*. I therefore regard this grass as a wonderful and most important discovery.

This grass is said to have been introduced into Georgia by General Iverson, of Columbus, and by him called rescue grass. The favorable opinion which it at first received does not seem to have been well sustained in that State.

Professor Phares, of Mississippi, says:

This grass is also called *Bromus Schraderi*, *B. Willdenovii*, *Ceratochloa unioloides*, and *Festuca unioloides*. It is an annual winter grass. It varies in the time of starting growth. I have seen it ready for mowing the first of October, and furnish frequent cuttings till April. Again, it may not start before January, nor be ready to cut till February. This depends on the moisture and depression of temperature of the fall, the seeds germinating only at a low temperature. When once started, its growth after the successive cuttings or grazings is very rapid. It is tender, very sweet, and stock eat it greedily. It makes also a good hay. It produces an immense quantity of leaves. On loose soil some of it may be pulled up by animals grazing it.

(Plate 112.)

BROMUS ERECTUS. (Erect Brome grass.)

This is a European species, which has become sparingly naturalized in some places. It is a perennial grass, growing about 2½ feet high, the culms erect, firm, and smooth. The leaves are narrowly linear, mostly radical, or at the base of the stem. The panicle is somewhat oblong in outline, 5 or 6 inches long, the branches mostly in fives, 1 to 2 inches long, slender, erect, not much subdivided, and each terminated with the pretty large spikelet of seven to nine flowers. The spikelets are about 1 inch long. The empty glumes are lanceolate, thinnish, acute, rather shorter than the flowering glumes, which are about five lines long, linear-lanceolate, slightly rough, and pointed with an awn of half to three-quarters its own length.

This species is not so coarse as many of the brome grasses, and will be more useful for hay. It is of the same genus as chess or cheat, but is very different from and should not be confounded with broom grass, which is an *Andropogon* and much less valuable. (Plate 113.)

We have several other native species of this genus, and there are several species growing in California, Oregon, and the mountain region of the Pacific slope. The most important of these is the *Bromus grandiflorus*, which is in many respects like the *Bromus unioloides*, but of a larger growth and with larger spikelets. *Bromus mollis*, *Bromus racemosus*, *Bromus sterilis*, and some other European species are occasionally found introduced.

LOLIUM PERENNE. (Rye grass and Italian Rye grass.)

A perennial grass, introduced from Europe. The culms are 2 to 3 feet high, very leafy, and terminating in a loose, spike-like panicle, 6 inches or more in length. The spikelets are arranged alternately on the axis, placed edgewise; that is, with one edge of the flat spikelet applied to the main stem at short distances, so that there may be twenty or more in the panicle. The spikelets are one-half to three-fourths of an inch long; generally seven to eleven flowered. The inner empty glume is generally wanting, so that, except on the terminal spikelet, only one glume is apparent, which is half or more than half the length of the spikelet, narrowly lanceolate, and acute. The general appearance of the panicle is like that of couch grass (*Triticum repens*). The flowering glumes are thickish, obscurely nerved, rather hispid, acutely pointed, or in the variety *Italicum*, with a longish awn. The proper palets are similar to the flowering glumes and of nearly equal length.

An intelligent writer, whom we have frequently quoted, says respecting this grass:

> It occupies the same place in Great Britain that timothy does with us, and is there esteemed on the whole higher than any other species of grass, and is called rye grass or ray grass. Of all the varieties of *Lolium perenne* which are known that called *Italicum* is by far the most valuable. Its spikelets are conspicuously bearded, the flowers being all terminated by long, slender awns, which character distinguishes it very easily from *Lolium perenne*. Its name (Italian rye grass) is derived from the fact

that its native habitat is on the plains of Lombardy, where broad and extensive plains of pasture land are frequently inundated by the mountain streams which intersect them. It is mainly adapted to irrigated meadows, and in these it is undoubtedly superior to any other grass.

Professor Phares says:

This grass stands drought well and grows most luxuriantly in our Southern States. If not kept grazed or mowed, however, the leaves cover the ground so deeply and densely that an excess of rain in very hot weather in the extreme South causes it to rot suddenly, destroying even the roots. This I have never seen or heard mentioned by any other person, but it occurred on my own farm one season, where I was reserving a lot for seed.

Hon. J. S. Gould says:

The valuable qualities of this grass may be summed up as follows: Its habit of coming early to maturity; its rapid reproduction after cutting; its wonderful adaptation to all domestic animals, which is shown by the extreme partiality they manifest for it, either alone or when mixed with other grasses, whether when used as green food for soiling, as hay or as pasturage, in which latter stage its stems are never allowed to ripen and wither like those of other grasses. One of its greatest recommendations is its beneficial influence on the dairy, not only in augmenting the flow of milk, but in improving the flavor of the cheese and butter that are made from it.

(Plate 114.)

AGROPYRUM. (*Triticum.*)

This genus is by many botanists considered as a section of *Triticum*, and our species are best known under that name. Tha spikelets are usually from three to five flowered, compressed, alternately sessile on the continuous or slightly notched axis of the simple spike and with the side of the spikelets against the axis; the outer glumes are nearly equal membranaceous or herbaceous, one to three nerved, scarcely keeled, tapering to a point, or awned; flowering glumes similar to the outer ones, but generally broader, rounded on the back, three to seven nerved, pointed or awned from the apex; the palet nearly as long as its glume, the two prominent nerves almost marginal and ciliate.

AGROPYRUM REPENS. (*Triticum repens.*) (Couch grass, Quack grass, Quitch grass, Wheat grass, Twitch grass, Dog grass.)

There has been a good deal of discussion relative to this grass, some pronouncing it one of the vilest of weeds, and others claiming for it high nutritive qualities overweighing all the disadvantages of its growth. Whichever party may be right, it is proper that farmers should be acquainted with it in order to know how to treat it, and hence our figure and description. It forms a dense sod by means of its far reaching rhizomas or root-stalks, which have short joints, and root tenaciously at every joint.

It has an abundance of foliage, and sends up a flowering culm, 2 to 4 feet high, which is terminated by a close, narrow spike of flowers from 3 to 6 inches long. This spike consists of a succession of closely-set spikelets, one at each joint of the axis, and placed flatwise with the side

against the stalk. Each spikelet contains several (three to eight) flowers, with a pair of nearly equal and opposite three to five nerved glumes at the base.

This grass as it occurs in the Eastern States is supposed to be introduced from Europe, but on the great Western plains and in the Rocky Mountains there are several varieties of it which are undoubtedly indigenous, as also several other species in the same region.

Hon. J. S. Gould says:

The farmers of the United States unite in one continuous howl of excreation against this grass, and it seems strange, when every man's hand is against it, that it is not exterminated. Yet we could never really satisfy ourselves that its presence in meadows and pastures was such an unmitigated curse. In lands where alternate husbandry is practiced, it must be admitted to be an evil of great magnitude. Its hardiness is such, and its rapidity of growth is so great that it springs up much more rapidly than any other crop that can be planted, and chokes it. Still it has many virtues. It is perfectly cosmopolitan in its habits. It is found in all sorts of soils and climates. Its creeping roots are succulent, and very nutritive, and are greedily devovoured by horses and cows.

Professor Phares, of Mississippi, says:

This is perennial, with stem 2 or 2½ feet high, so much like wheat as to be called also wheat grass. Cattle eat it heartily when green, and cut early it makes a good hay. But it fills the ground with roots, is as difficult to cultivate amongst and exterminate as coco or nut grass; and hogs are as fond of and root up the ground as industriously to obtain the roots. Cows and horses are also fond of them. It should be destroyed as soon as found in cultivated ground, but it is very valuable in permanent pastures.

(Plate 115.)

AGROPYRUM GLAUCUM. (Blue stem, Blue joint.)

This species, which has also been considered a variety of the preceding, prevails on the Western plains from Texas to Montana, and is well known to stockmen. It differs from the *A. repens* in having a stouter, more rigid stem and leaves; the leaves, indeed, often becoming involute and stiff. It is also of a light bluish-green color. The spike is generally shorter, denser, and with larger spikelets.

Mr. Richard Gaines, of Colorado Springs, Colo., says:

We think this is the best grass grown, superior to timothy or clover. We call it blue stem, or blue joint; no richer hay can be made from anything known.

HORDEUM NODOSUM. (Barley grass.)

An annual or biennial grass, growing principally in alkaline soils and on the borders of saline marshes, especially in the Western States and Territories. Although eaten by cattle when in a young state, it cannot be claimed as of anything more than temporary value. The culms are usually 1 to 1½ feet high, sometimes in moist places reaching 3 feet, and varying as to smoothness or pubescence. The leaves are usually flat, 2 to 4 inches long, and about two lines wide. The flowers are in a close, cylindrical spike, about 2 inches long, with three spikelets at each joint of the rachis. One (the central) spikelet is sessile and perfect; the two

lateral ones are short-stalked and imperfect or abortive. Each of the spikelets has a pair of empty glumes, which are narrowly lanceolate and awn-pointed, or the lateral ones may be reduced to rough bristles. The flowering glume of the perfect flower is lanceolate, indistinctly three-nerved, and terminated by an awn one-quarter to one-half inch long, equaling those of the empty glumes. The proper palet is inclosed in its glume, is of about the same length as that, excluding the awn, and of thinner texture. (Plate 116.)

HORDEUM JUBATUM. (Wild barley, Squirrel tail grass.)

This species has the same general characters as the preceding, but the flowers have awns 2 inches or more long, giving it a bushy and rather handsome appearance. It is frequently found in wet or marshy places and is of no agricultural value.

HORDIUM MURINUM.

Professor Brewer states that this grass, unfortunately is extensively naturalized in California, and is a vile pest; it comes in when land is overstocked; is known there as "Squirrel grass," "Squirrel tail," "Fox tail," and "White oats." The heads break up and the barbed seeds work into the wool of sheep, and even into the flesh of lambs, killing them. It damages the eyes and throats of animals.

ELYMUS. (Wild rye.)

Of this genus we have several species. Its general characters are as follows: Spikelets in a simple, generally stout, spike, sessile, two to four at each joint of the axis, one to six flowered; outer glumes two for each spikelet, nearly side by side in front, forming a kind of involucre for the cluster, narrow, rigid, one to three nerved, acuminate or awned; flowering glumes herbaceous, thick and harsh, oblong or lanceolate, rounded on the back, not keeled, acute, or awned; palet shorter than its glume acute, two-keeled.

ELYMUS CANADENSIS. (Wild rye, Lyme grass, Terrell grass.)

A perennial coarse grass, growing on river banks and in rich shaded woods. Culms, 2 to 4 feet high, leafy, terminated by a cylindrical loose spike, 4 to 8 inches long, with the spikelets placed at intervals of about half an inch on the axis. The spikelets are mostly in pairs at each joint, each composed of from three to five flowers. The glumes are narrow, strongly nerved, and tapering to an awn which is rather shorter than the awn of the flowers proper. The flowering glume of each flower is thick in texture, narrow, and extending into a long, somewhat curved awn or beard, the palet with the awn being an inch or more in length. The palet is thinner in texture, obtuse, and not awned, fringed with short hairs on the margin. The spike is usually drooping at the top and rather graceful in appearance. The leaves are broad and rough, the lower ones 9 to 12 inches long.

In some localities this is common in low meadows, and is cut with other native grasses for hay. If left until maturity it becomes too coarse to be of much value. In some portions of the Southern States this grass is known as Terrell grass from having been prominently brought to notice by Dr. Terrell, of Sparta, Ga. Mr. C. W. Howard writes concerning it, as follows:

This grass will live on thin land, but the soil, to make it valuable, must be rich—the richer the better. It lasts for years. I have known it to occupy and flourish on the same spot for twenty years. Horses, sheep, and cattle are very fond of it during the winter and spring; hogs reject it. Orchard, blue, or meadow-oat grass are either of them preferable to it where they thrive. Whatever doubt there may be of their thriving in a given locality, there can be no doubt of the thrift of the Terrell grass in any part of the South, however hot it may be, if the soil be made rich. The planter living in the flat and somewhat sandy portions of the South who says he cannot get a good winter pasture, has certainly never tried the Terrell grass on rich land.

(Plate 117.)

ELYMUS VIRGINICUS. (Wild Rye grass, Smooth Rye grass, Terrell grass.)

A coarse perennial grass, growing on alluvial river banks or in rich low grounds. The culm is rather stout, 2 to 3 feet high, leafy; the lower leaves are 10 to 15 inches long, broad and rough. The sheath of the upper leaf usually incloses the stock, and sometimes the base of the flower spike. This spike is erect, dense, and rigid, 2 to 4 or 5 inches long and one-half inch thick. The spikelets are two or three together at each joint, all alike and fertile, sessile, two to five flowered, and each with a pair of empty glumes. These glumes are very thick and coarse, strongly nerved, lanceolate, and bristle-pointed, about 1 inch long. The flowering glumes are of firm texture, lance-oblong, five-nerved, hairy on back, and terminating in a stiff, straight awn, half an inch to nearly an inch long. The lowest one in the spikelet having the longest awn, the others gradually shorter. The palet is oblong, obtuse, and as long as the flowering glume, excluding the awn.

This grass frequently forms a considerable portion of native meadow lands and makes a coarse hay. It starts growth early in the spring, and thus affords a good pasturage. Professor Killebrew, of Tennessee, says it is very valuable and ought to be tried in cultivation.

Professor Phares, of Mississippi, says:

This perennial grass is a native of the Southern States. As all farm stock except hogs are fond of it, and it is green through the winter and spring, it has been destroyed when grazing animals have access to it at all times. It is, however, found in many of our States along the banks of wooded streams, of ditches, and in fence-corners among briers and thickets. It will grow on thin clay, gravelly, or sandy soil, but much better on rich lands, dry or rather moist, and will thrive ten, twenty, or more years on the same land.

(Plate 118.)

ELYMUS STRIATUS. (Smaller Rye grass, Dennett grass).

This grass has a structure as to the flower-spike similar to the preceding, but it is a more slender grass in all its parts, varying from smooth to pubescent. The spike is 3 to 4 inches long, cylindrical, and inclined to droop. The glumes are more slender than in *E. Virginicus*, with longer awns. The spikelets are usually two-flowered, the empty glumes narrow, rigid, and about 1 inch long. The body or dilated part of the flowering glume is oblong, about four lines long, and tipped with a slender awn an inch or more in length.

This species grows in rocky woods and on river banks, growing more sparsely than the preceding, and it is said by some to furnish a good hay.

Professor Phares says of this species:

This, also, is a perennial and a native of the Southern States. Everything said of the preceding, *E. Virginicus*, applies with equal force to this, except the spikes of this are 3 to 7 inches long, and often slightly nodding. Also the spike of this species is raised by its long peduncle far above the sheath of the upper leaf, while the spike of the other is partly included in the upper sheath. They may be grazed or mown repeatedly during spring and early summer, and grow rapidly after each mowing. Many acres have been planted in the last few years. As hay it is rather hard unless cut when young. It should be cut as soon as the blooms appear or earlier. It would be preferable to have these grasses for grazing or soiling, and to sow better grasses for hay.

(Plate 119.)

ELYMUS CONDENSATUS. (Giant Rye grass, Western Rye grass.)

This is a perennial grass, ranging from San Diego throughout California, and into Oregon and Washington Territory, also in the Rocky Mountain region of the interior. It is very variable, but always a strong, heavy-rooted, coarse grass, from 3 to 5 or even to 12 feet high. Mr. Bolander states that it seems to do excellent service by fixing the soil on the banks of creeks and rivers. In the larger forms the culms are half an inch thick. The leaves are smooth, 2 feet long and an inch wide, or more, and the panicle 8 to 14 inches long and 1½ inches thick. As it usually occurs in arid grounds it is from 3 to 6 feet high, the leaves about a foot long and half an inch wide, and the spike-like panicle 4 to 8 inches. In the large form the branches of the panicle are subdivided and 1 or 2 inches long.

More commonly there are two to five sessile spikelets at each joint of the axis, the spikelets about three-flowered. The outer glumes are subulate or short, bristle-like. The flowering glumes are mostly coriaceous, five-nerved, rounded on the back, and acute or mucronate pointed.

There is a variety called *Triticoides*, which has a more slender, less crowded spike, the spikelets more distant, not more than two at a joint, and frequently single, the culm more slender, and the leaves narrow or involute. This variety seems to unite the genus to *Triticum*. (Plate 120.)

GLOSSARY OF TERMS USED IN DESCRIBING GRASSES.

Abrupt. Terminating suddenly.
Acuminate. Extended into a tapering point.
Acute. Sharp-pointed.
Alternate. Situated regularly one above the other on opposite sides.
Annual. Living but one season.
Anther. The organ containing the pollen or flower dust.
Apex. The top or extreme end of any part.
Appressed. Pressed together, not spreading.
Aristate. Having an awn or beard.
Articulated. Connected by a joint or joints.
Ascending. Rising obliquely from the ground.
Awl-shaped. Gradually narrowed to a fine point like an awl.
Awn. A bristle-like hair proceeding from the glumes.
Axis. The central stem of a panicle, spike, or spikelet on which the flowers are disposed.
Beard. A long slender hair or awn.
Biennial. Living through two seasons.
Bifid. Divided into two portions at the apex.
Bisexual. Having both stamens and pistils.
Blade. The expanded portion of a leaf.
Boat-shaped. Folded together in the form of a boat, convex outwardly and concave on the inside.
Branch. A division of the stem or panicle.
Branchlet. A secondary division of the branch.
Bristles. Short, stiff hairs.
Bulbous. Thickened like a bulb.
Cæspitose. Growing in bunches or tufts.
Capillary. Hair-like, very slender.
Cartilaginous. Firm and tough like cartilage.
Carinate. Keeled, having a prominent ridge in the center.
Cauline. Belonging to the culm or stem.
Chaff. The dried glumes and palets of grasses.
Chartaceous. The texture resembling paper or parchment in thickness.
Ciliate. Having the margin or nerves fringed with hairs.
Compressed. Flattened laterally.
Contorted. Twisted.
Convolute. Rolled together inward from the margins.
Cornaceous. Of a horn-like consistence.
Coriaceous. Of a leathery consistence.
Culm. The stalk or stem of grasses.
Cuspidate. Ending in a sharp, stiff point.
Decumbent. Reclining on the ground, but rising at the top.
Dichotomous. Branching in twos, forking by pairs.
Digitate. Dividing from a common point.
Dioecious. Having the stamens and pistils on separate plants, the staminate flowers on one and pistilate flowers on another.
Diverging. Widely spreading.
Dorsal. Belonging to or growing from the back.
Emarginate. Having a notch at the end.
Entire. Without notches or divisions.
Equal. Alike in length.
Exserted. Protruded, extended beyond, standing out.

Fertile. Having perfect pistils, producing fruit.
Fibrous. Having thread-like divisions.
Filament. The stalk or support of the anther.
Filiform. Thread-like.
Flexuous. Bending freely.
Floret. The flowers of grasses are sometimes called florets.
Foliaceous. Resembling a leaf.
Fusiform. Spindle-shaped, largest in the middle and tapering to both ends.
Geniculate. Bent abruptly at an angle, like a knee.
Genus. A group of species having a general agreement in structure.
Glabrous. Smooth, without hairs or roughness.
Glaucous. Having a light bluish-green color.
Glomerate. Clustered in small roundish heads.
Glumes. The chaff-like leaves forming a part of the flowers.
Herbaceous. Herb-like, not woody.
Hirsute. Pubescent, with rather stiff and coarse hairs.
Hyaline. Thin and transparent.
Indigenous. Growing naturally, not brought from some other country.
Inferior. Lower in position.
Inserted. Growing out of, or upon another.
Internode. The space between two nodes or joints.
Involute. Rolled together inwards.
Imbricate. Closely overlapping each other, as frequently the flowers of a spikelet.
Joints. Thickenings in the stem where the leaves originate; separable parts of an axis; point of issue of the branches of a panicle.
Keel. An elevated longitudinal ridge, in the middle of a leaf, glume, or palet; resembling the keel of a boat.
Lamina. The free or expanded portion of a leaf, as distinguished from the petiole or the sheath; the blade of a leaf.
Lanceolate. Tapering gradually to the apex, like a lancet.
Lateral. At or from the side.
Ligule. A tongue-like appendage at the upper part of the sheath of a leaf.
Line. The twelfth part of an inch.
Linear. Long and narrow, with parallel sides.
Lobe. Some division of a glume.
Male flower. A flower that has stamens, but without pistil.
Membranaceous. Thin like a membrane, generally somewhat translucent.
Monœcious. With stamens and pistils.
Midrib. The central and principal nerve of a leaf or glume.
Mucronate. Abruptly tipped with a short awn or bristle.
Nerves. The ribs or veins of a leaf, or leaf-like organ.
Neutral. Having neither stamens nor pistils.
Nodes. Knots or thickened portions in the culms.
Oblong. Longer than wide, with nearly parallel sides
Obovate. Egg-shaped, with the wider end uppermost.
Obtuse. Blunt or rounded at the apex.
Oval. Broadly elliptical, approaching the round form.
Ovary. That part of the pistil which contains the seed.
Ovate. Egg-shaped.
Palet or palea. The inner scale or chaff of the proper flower, placed nearly opposite and a little higher on the axis than the flowering glume.
Panicle. A branched and subdivided stem bearing the flowers.
Pedicel. A small branchlet supporting a spikelet.
Peduncle. The main stem or stalk of a flower spike.
Perennial. Living more than two years, or indefinitely.

Perfect. Having both stamens and pistils.
Petiole. The stem of a leaf.
Pistil. The central or female organ of a fertile flower.
Pistillate. Having only pistils without stamens.
Plumose. Feather-like.
Pollen. The powder contained in the anthers.
Pubescent. Clothed with short and soft hairs.
Radical leaves. Those growing from the base of the culm.
Revolute. Rolling backwards or outwards.
Rhachis. The axis or stem on which the flowers of a spikelet are arranged; also the common axis of a close spike or of a panicle.
Rhizoma or rootstock. A horizontal underground stem.
Ribs. Prominent nerves of the leaves or glumes.
Rugose. Wrinkled or furrowed.
Scabrous. Rough, with small points or hairs.
Scarious. Dry and thin, and generally transparent.
Sericeous. Covered with soft, silky hairs.
Serrate. Having teeth on the margin, pointed toward the apex.
Serrulate. Finely-toothed.
Sessile. Without a foot stalk or pedicel.
Setaceous. Like a bristle.
Sheath. That part of the leaf which embraces the culm or stalk.
Spike. A collection of sessile or nearly sessile flowers on a close, narrow axis.
Spikelet. A flower or cluster of flowers having one pair of outer glumes.
Stamen. The male organs of a flower, including the anther and filament.
Staminate. Having only stamens.
Sterile. Imperfect flowers not producing seed.
Strict. Erect and close.
Stoloniferous. Sending off offshoots or runners from the base.
Strigose. Having spreading, bristly hairs.
Subulate. Stiff and linear, shaped like an awl.
Succulent. Fleshy and juicy.
Style. That portion of the pistil bearing stigmas or a stigmatic surface; in grasses often branching.
Truncate. Abruptly cut off at the apex.
Unequal. Not of equal length.
Verticillate. Arranged in a whorl or whorls.
Villous. Velvety, clothed thickly with long, soft hairs.
Whorl. A number of leaves or branches arranged around a stem on the same plane.
Wooly. Clothed with long and matted hairs.

THE CHEMICAL COMPOSITION

OF

AMERICAN GRASSES

FROM

INVESTIGATIONS IN THE LABORATORY OF THE DEPARTMENT OF AGRICULTURE, 1878–1882.

BY

CLIFFORD RICHARDSON,
ASSISTANT CHEMIST.

THE CHEMICAL COMPOSITION OF AMERICAN GRASSES.

In submitting grasses to chemical analysis, with a view of judging of their nutritive value, it is usual to determine the amount present of water, ash, fat or oil, fiber and nitrogen. From the latter the amount of albuminoids to which it is equivalent is readily calculated by multiplying by a factor which represents the per cent. of nitrogen present in the average albuminoid, and by subtracting the sum of all these constituents from one hundred, the percentage of undetermined matter is obtained, and as it of course contains no nitrogen, and consists of the extractive principles of the plant, it is described as "Nitrogen free extract." It includes all the carbo-hydrates, such as sugar, starch, and gum, together with certain other allied substances, with which we are less intimately acquainted, but which have a certain nutritive value.

Although it has been customary to state as albuminoids the equivalent of the nitrogen found, this is rarely entirely correct, as a portion is generally present in a less highly elaborated form of a smaller nutritive value. This portion is described as non-albuminoid nitrogen, and in analyses of the present day the amount is always given as an additional source of information, although our knowledge of its exact value to the animal is rather uncertain.

The ultimate composition of the ash is also frequently determined, and examples of the results obtained are of interest, as showing the mineral matter that grasses withdraw from the soil.

Without entering into a discussion of the nutritive value of the several constituents of the grasses, for which reference can be made to Armsby's Manual of Cattle Feeding, it is sufficient to say that during the past few years the greater portion of the species described by Dr. Vasey in the preceding portion of this bulletin have been analyzed, and the results collected and rearranged, with some corrections, from the annual reports of the Department are presented in the following pages.

The first series consists of analyses made with specimens collected at or near the time of blooming. Their origin is as follows:

No. of anal.

1. *Paspalum laeve* (Water grass). From Prof. S. B. Buckley, Austin, Tex. 1878.
2. *Paspalum laeve* (Water grass). From the Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. 1880, August 23–29.
3. *Paspalum ovatum*.. From S. L. Goodale, Saco, Me. 1880.
4. *Paspalum praecox*. From Charles Mohr, Mobile, Ala. 1879.
5. *Digitaria filiforme*. From Charles Mohr, Mobile, Ala. 1878.

No. of anal.

6. *Digitaria sanguinale* (Crab grass). From Charles Mohr, Mobile, Ala. 1878.
7. *Digitarria sanguinale* (Crab grass). From the grounds of the Department. June 23, 1880.
8. *Digitaria sanguinale* (Crab grass). From the Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. August 11, 1880.
9. *Panicum jumentorum*. From Charles Mohr, Mobile, Ala. 1878.
10. *Panicum Texanum* (Texas millet). From Prof. S. B. Buckley, Austin, Tex. 1879.
11. *Panicum proliferum* (Large Crab grass). "Very ripe and rank." From Charles Mohr, Mobile, Ala. 1879.
12. *Panicum agrostoides* (Marsh panic). From W. S. Robertson, Muscogee, Ind. T. 1879.
13. *Panicum anceps*. From Charles Mohr, Mobile, Ala. 1879.
14. *Panicum anceps*. From the Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. July 31, 1880.
15. *Panicum crus-galli* (Barn-yard grass). From Charles Mohr, Mobile, Ala. 1879.
16. *Panicum crus-galli* (Barn-yard grass). From Prof. S. B. Buckley, Austin, Tex.
17. *Panicum crus-galli* (Cock's foot). From the Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. August 25, 1880.
18. *Panicum virgatum* (Panic grass). From W. S. Robertson, Muscogee, Ind. T. 1879. Low growth.
19. *Panicum virgatum* (Tall panic or switch grass). From Prof. S. B. Buckley, Austin, Tex. 1878.
20. *Panicum virgatum* (Tall panic or switch grass). From Charles Mohr, Mobile, Ala. 1878.
21. *Panicum virgatum* (Tall panic or switch grass). From W. S. Robertson, Muscogee, Ind. T. 1879. Tall growth.
22. *Panicum diraricatum*. From Charles Mohr, Mobile, Ala. 1879.
23. *Panicum gibbum*. From Charles Mohr, Mobile, Ala. 1879.
24. *Panicum obtusum*. From Prof. S. B. Buckley, Austin, Tex. 1878.
25. *Panicum capillare* (Witch grass). From W. S. Robertson, Muscogee, Ind. T. 1879.
26. *Panicum dichotomum*. From Charles Mohr, Mobile, Ala. 1879.
27. *Setaria Italica*. From the Eastern Experiment Farm, West Grove, Chester County Pennsylvania. July 24, 1880.
28. *Setaria glauca* (Foxtail). From the grounds of the Department. July 24, 1880.
29. *Setaria glauca* (Foxtail). From the Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. August 11, 1880.
30. *Setaria setosa* (Bristle grass). From Prof. S. B. Buckley, Austin, Tex. 1878.
31. *Tripsacum dactyloides* (Gama grass). From D. L. Phares, Woodville, Miss. 1878.
32. *Tripsacum dactyloides* (Gama grass). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. 1880.
33. *Spartina cynosuroides* (Whip grass). From A. C. Lathrop, Glenwood, Pope County, Minnesota. 1879.
34. *Spartina cynosuroides* (Whip grass). From J. D. Waldo, Quincy, Ill. 1879.
35. *Spartina cynosuroides* (Whip grass). From W. S. Robertson, Muscogee, Ind. T. 1879.
36. *Andropogon Virginicus* (Brown sedge, Sedge grass). From Prof. S. B. Buckley, Austin, Tex. 1878.
37. *Andropogon scoparius*. From Charles Mohr, Mobile, Ala. 1879. Before bloom.
38. *Andropogon scoparius* (Broom grass). From Charles Mohr, Mobile, Ala. 1878.
39. *Andropogon scoparius*. From W. S. Robertson, Muscogee, Ind. T. 1879.
40. *Andropogon macrourus* (Broom grass). From Charles Mohr, Mobile, Ala.
41. *Andropogon furcatus* (Blue joint grass). From A. C. Lathrop, Glenwood, Pope County, Minnesota. 1879.

No. of anal.

42. *Andropogon furcatus* (Blue joint). From D. H. Wheeler, Nebraska. 1879.
43. *Andropogon furcatus* (Blue joint). From W. S. Robertson, Muscogee, Ind. T. 1879.
44. *Andropogon furcatus* (Blue joint grass). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. September 2, 1880.
45. *Andropogon argenteus* (Silver Beard grass). From W. S. Robertson, Muscogee Ind. T. 1880.
46. *Sorghum halapense* (Johnson grass.) From Charles Mohr, Mobile, Ala. 1878.
47. *Sorghum nutans.* From W. S. Robertson, Muscogee, Ind. T. 1879.
48. *Sorghum nutans* (Wood grass). From Prof. S. B. Buckley, Austin, Tex. 1878.
49. *Phalaris intermedia*, var. *angusta* (American Canary grass). From South Carolina, 1879.
50. *Anthoxanthum odoratum*, (Sweet Vernal grass). From James O. Adams, Manchester, N. H. 1879.
51. *Anthoxanthum odoratum* (Sweet Vernal grass). From the Eastern Experimental Farm, West Grove, Chester County, Pennsylvania. May 11–24, 1880.
52. *Anthoxanthum odoratum* (Sweet Vernal grass). From the grounds of the Department. May, 1 1880.
53. *Hierochloa borealis* (Vanilla grass). From E. Hall, Athens, Ill. 1878.
54. *Alopecurus pratensis* (Meadow foxtail). From the grounds of the Department. May 1, 1880.
55. *Aristida perpurascens* (Purple Beard grass). From W. S. Robertson, Muscogee, Ind. T.
56. *Milium effusum.* From C. G. Pringle, Hazen's Notch, Vt. 1880.
57. *Muhlenbergia diffusa* (Drop-seed grass). From Prof. S. B. Buckley, Austin, Tex. 1878.
58. *Muhlenbergia diffusa* (Drop-seed grass). From Eastern Experimental Farm, West Grove, Chester County, Pennsylvania. Aug. 25, 1880.
59. *Muhlenbergia Mexicana.* From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. Aug. 22, 1880.
60. *Muhlenbergia glomerata* (Satin grass). From A. C. Lathrop, Glenwood, Pope County, Minnesota. 1879.
61. *Muhlenbergia* sp? (Knot grass). From James O. Adams, Manchester, N. H. 1879. 1879.
62. *Phleum pratense* (Timothy, Herd grass). From the grounds of the Department. June 18, 1880.
63. *Phleum pratense* (Timothy). From the grounds of the Department. Wayside growth. June 4, 1880.
64. *Phleum pratense* (Timothy). From the grounds of the Department. June 26, 1882. First year's growth from seed.
65. *Phleum pratense* (Timothy). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. June 20, 1880.
66. *Phleum pratense* (Timothy, Herd grass). From J. W. Sanborn, Hanover, N. H. 1881.
67. *Phleum pratense* (Timothy). From W. H. Hackstaff, La Fayette, Ind. 1882.
68. *Phleum pratense* (Timothy). From J. M. Robinson, Queen Anne County, Maryland. July 4, 1882. Unmanured for years.
69. *Sporobolus Indicus* (Sweet grass). From D. L. Phares, Woodville, Miss. 1878.
70. *Agrostis vulgaris* (Red Top, Herd grass). From the grounds of the Department. June 23, 1880.
71. *Agrostis vulgaris* (Red Top). From the grounds of the Department. Wayside growth. June 18, 1880.
72. *Agrostis vulgaris* (Herd grass). From the Eastern Experimental Farm, West Grove Chester County, Pennsylvania.
73. *Agrostis vulgaris* (Red Top). From J. J. Rosa, Milford, Del.

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74. *Agrostis exarata* (Native Red Top). From Theo. Louis, Louisville, Wis. 1878.
75. *Cinna arundinacea* (Reed grass). From W. S. Robertson, Muscogee, Ind. T.
76. *Holcus lanatus* (Velvet grass). From the grounds of the Department. May 25, 1880.
77. *Avena striata* (Mountain Oat grass). From Cyrus G. Pringle. Charlotte, Vt. 1879.
78. *Arrhenatherum avenaceum* (Oat grass). From the grounds of the Department. May 25, 1880.
79. *Arrhenatherum avenaceum* (Oat grass). From Dr. W. C. Benbow, Greensboro', N. C. Late bloom. May 12, 1880.
80. *Danthonia spicata* (Wild Oat grass). From James O. Adams, Manchester, N. H. 1879.
81. *Danthonia compressa* (Wild Oat grass). From Cyrus G. Pringle, Charlotte, Vt. 1874.
82. *Cynodon dactylon* (Bermuda grass). From Charles Mohr, Mobile, Ala. 1878.
83. *Cynodon dactylon* (Bermuda grass). From D. L. Phares, Woodville, Miss. 1878.
84. *Bouteloua oligostachya* (Gamme grass). From A. C. Lathrop, Glenwood, Pope County, Minnesota. 1879.
85. *Eleusine Indica* (Yard grass, Crow-foot grass). From Prof. S. B. Buckley, Austin, Tex.
86. *Eleusine Indica* (Yard grass, &c.). From Dr. W. A. Creswell, Americus, Ga. 1878.
87. *Eleusine Indica* (Yard grass, &c.). From Charles Mohr, Mobile, Ala. 1878.
88. *Leptochloa mucronata* (Feather grass). From Prof. S. B. Buckley, Austin, Tex. 1878.
89. *Triodia purpurea* (Sand grass). From W. S. Robertson, Muscogee, Ind. T. 1879.
90. *Triodia sesleroides* (Tall Red Top). From Prof. S. B. Buckley, Austin, Tex. 1878.
91. *Uniola latifolia* (Fescue grass). From Charles Mohr, Mobile, Ala. 1879.
92. *Uniola latifolia* (Fescue grass). From M. S. Robertson, Muscogee, Ind. T. 1879.
93. *Dactylis glomerata* (Orchard grass). From James O. Adams, Manchester, N. H. 1879.
94. *Dactylis glomerata* (Orchard grass). From the grounds of the Department, May 13, 1880. First growth.
95. *Dactylis glomerata* (Orchard grass). From the grounds of the Department, June 18, 1880. Later growth.
96. *Dactylis glomerata* (Orchard grass). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. 1880.
97. *Dactylis glomerata* (Orchard grass). From W. H. Cheek, Warren County, North Carolina. Early bloom. May 16, 1880.
98. *Dactylis glomerata* (Orchard grass). From Dr. W. C. Benbow, Greensboro', N. C. 1880. Early bloom, May 12.
99. *Dactylis glomerata* (Orchard grass). From S. L. Goodale, Saco, Me. 1880.
100. *Poa pratensis* (Blue grass, June grass). From Theo. Louis, Louisville, Wis. 1873.
101. *Poa pratensis* (Blue grass, &c.). From James O. Adams, Manchester, N. H. 1879.
102. *Poa pratensis* (Blue grass, &c.). From the grounds of the Department. May 23, 1880. Growth from best soil.
103. *Poa pratensis* (Blue grass, &c.). From the grounds of the Department. May 6, 1880. Growth from poorer soil.
104. *Poa pratensis* (Blue grass, &c.). From the grounds of the Department. May 19, 1880. Growth by wayside.
105. *Poa pratensis* (Blue grass, &c.). From J. D. Waldo, Quincy, Ill. May 17, 1880.
106. *Poa pratensis* (Blue grass, &c.). From W. B. Cheek, Warren County, North Carolina. 1880. Before bloom.

No. of anal.

07. *Poa pratensis* (Blue grass, &c.). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. 1880.

08. *Poa compressa* (English Blue grass, Wire grass). From James O. Adams, Manchester, N. H. 1879.

09. *Poa compressa* (English Blue grass). From the grounds of the Department. June 17, 1880.

10. *Poa compressa* (English Blue grass). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. June 10, 1880.

11. *Poa compressa* (English Blue grass). From J. J. Rosa, Milford, Del. June 6, 1880.

12. *Poa serotina* (Fowl-meadow grass, False red top). From Theo. Louis, Louisville, Wis. 1878.

13. *Poa arachnifera*. From Ellis County, Texas. 1882.

14. *Poa alsodes*. From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. June 2, 1880.

15. *Glyceria aquatica* (Reed Meadow grass). From Cyrus G. Pringle, Charlotte, Vt. 1879.

16. *Glyceria nervata* (Fowl Meadow grass). From Cyrus G. Pringle, Charlotte, Vt. 1879.

17. *Glyceria nervata* (Fowl Meadow grass). From James O. Adams, Manchester, N. H. 1879.

18. *Glyceria nervata* (Fowl Meadow grass). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. June 2, 1880.

19. *Festuca orina* (Sheep's Fescue). From James O. Adams, Manchester, N. H. 1879.

20. *Festuca orina* (Sheep's Fescue). From the grounds of the Department. May 21, 1880.

21. *Festuca elatior* (Meadow Fescue). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania. June 2, 1880.

22. *Festuca pratensis* (Meadow Fescue). From James O. Adams, Manchester, N. H. 1879.

23. *Festuca pratensis* (Field Fescue). From the grounds of the Department. June 1, 1880. After bloom.

24. *Bromus secalinus* (Cheat or Chess). From James O. Adams, Manchester, N. H. 1879.

25. *Bromus unioloides* (Schrader's grass). From the grounds of the Department. 1879.

26. *Bromus unioloides* (Schrader's grass). From the grounds of the Department. May 13, 1880.

27. *Bromus erectus* (Chess). From the grounds of the Department. May 19, 1880.

28. *Bromus carinatus* (California Brown grass). From E. Hall, Athens, Ill. 1878.

29. *Lolium perenne* (Common Darnel, Ray, or Rye grass). From the grounds of the Department. June 1, 1880.

30. *Lolium perenne* (Rye grass, &c.). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania.

31. *Lolium Italicum* (Italian Rye grass). From the grounds of the Department. May 26, 1882.

32. *Agropyrum repens* (Couch, Quitch, or Quick grass). From James O. Adams, Manchester, N. H. 1879.

33. *Agropyrum repens* (Couch grass, &c.). From Eastern Experiment Farm, West Grove, Chester County, Pennsylvania.

34. *Agropyrum repens* (Couch grass). From S. L. Goodale, Saco, Me. 1880.

35. *Agropyrum repens* (Couch grass, &c.). From the grounds of the Department. June 23, 1880. Early bloom.

36. *Elymus canadensis* (Wild Rye grass). From D. H. Wheeler, Nebraska. 1879.

The specimens, it will be seen, are from all parts of the country and grown under every condition of soil and environment. Those collected by Dr. Peter Collier in 1878 and 1879 were mostly from the poorer soils and were intended to represent the wild grasses of the country. Those collected in subsequent years by myself were chiefly cultivated varieties. The development in nearly every case was full bloom or shortly after, that being the period at which the grasses as a whole seem to be cut for hay.

The analyses have been calculated for "dry substance" and also for "fresh grass" where the amount of water in the fresh grass had been determined, otherwise for the average amount of water in hay as given by Wolff. This figure is probably too high for the United States owing to our drier climate, but, in the absence of exact data for the selection of a more accurate one, it has been provisionally accepted. It is very easily to calculate from the composition of the dry substance what effect the presence of any percentage of water would have on the absolute amount of any constituent present in a given weight of grass.

No. of analysis.		Specimen No.	Date cut.	Locality.	Height.	Dry substance.								Fresh substance or hay.					
						Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoid.	Per cent. of nitrogen as non-albuminoid.	Water.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.
1	Paspalum læve	1	1878.	Tex	..	7.70	2.75	53.83	27.61	8.11	1.30	.62	47.5	14.30	6 60	2.36	46.13	23.66	6.95
2	..... do	2	1880. Aug. 23–9	Pa	..	6.90	2.16	59.27	23.50	8.17	1.31	.38	29.0	14.30	5.91	1.85	50.80	20.14	7.00
3	Paspalum ovatum	3	.....	Me	....	8.49	2.21	58.42	24.75	6.13	.98	.26	26.5	14.30	7.28	1.89	50.07	21.21	5.25
4	Paspalum precox	4	1879.	Ala	....	7.41	3.60	57.75	25.31	5.93	.95	.25	26.2	14.30	6.35	3.09	49.49	21.69	5.08
5	Digitaria filiforme	5	.. ..	Ala	...	8.76	1.48	60.95	25.83	2.98	.48	.00	0.0	14.30	7.57	1.27	52.24	22.14	2.54
6	Digitaria sanguinale	6	1878.	Ala	.. ....	12.61	2.82	42.70	32.09	9.78	1.57	.51	32.6	14.30	10.81	2.42	36.59	27.50	8.38
7	..... do	7	June 23, '80	D C	52	15.01	4.84	37.99	19.03	23.13	3.70	.....	.....	76.50	3.53	1.13	8.93	4.47	5 44
8	..... do	8	Aug. 11, '80	Pa	....	11.45	3.26	50.56	22.90	11.83	1.89	.81	42.6	14.30	9.81	2.79	43.33	19.63	10.14
9	Panicum jumentorum	9	1878.	Ala	....	9.04	1.57	48.98	31.52	8.89	1.42	.74	52.0	14.30	7.75	1.34	41.98	27.01	7.62
10	Panicum Texanum	10	1878.	Tex	....	10.10	2.47	54.93	27.02	5.48	.88	.33	37.5	14.30	8.65	2.12	47.07	23.16	4.70
11	Panicum proliferum	11	1879.	Ala	....	11.17	3.01	50.97	24.07	11.08	1.77	.63	35.7	14.30	9.58	2.58	43.42	20.63	9.49
12	Panicum agrostoides	12	....	Ind. T	....	6.69	5.69	50.87	30.86	5.89	.94	.39	41.1	14.30	5.73	4.88	43.59	26.45	5.05
13	Panicum anceps	13	.....	Ala	...	9.05	1.83	55.50	27.84	5.78	.92	.19	21.0	14.30	7.76	1.57	47.56	23.89	4.95
14	do	14	July 31	Pa	..	5.68	1.82	62.59	20.88	9.03	1.44	.44	30.7	14.30	4.87	1.56	53.64	17.89	7.74
15	Panicum Crus-Galli	15	.....	Ala	...	6.98	2.15	54.19	28.91	7.77	1.24	.45	36.5	14.30	5.98	1.84	46 44	24.78	6 66
16	..... do	16	.....	Tex	..	16.07	2.04	46.77	31.13	3.99	.64	.15	23.7	14.30	13.77	1.75	40.08	26.68	3.42
17	.... do	17	Aug. 25	Pa	....	11.82	2.49	47.77	25.32	12.60	2.02	.80	39.5	14.30	10.13	2.13	40.95	21.69	10.80
18	Panicum virgatum	18	.....	Ind. T	....	5.49	3.33	56.95	29 11	5.12	1.00	.49	49.2	14.30	4.70	2.85	48.81	24.95	4.39
19	..... do	19	.....	Tex	...	7.24	1.66	49.39	36.78	4.93	.78	.18	23.3	14.30	6.20	1.42	42.33	31.52	4.23
20	..... do	20	.....	Ala	....	3.74	1.92	60.95	28.82	4.57	.73	.31	41.8	14.30	3.20	1.65	52.23	24 70	3.92
21	..... do	21	.....	Ind. T	...	4.57	2.98	57.40	32.25	2.80	.45	.21	47.6	14.30	3.92	2 55	49.19	27.64	2.40
22	Panicum divaricatum	22	.....	Ala	....	14.29	2.52	46.89	27.06	9.24	1.48	.36	24.6	14.30	12.25	2.16	40.18	23.19	7.92
23	Panicum gibbum	23	1878.	Ala	...	8.53	4.16	50.93	24.16	12.22	1.96	.83	42.6	14.30	7.31	3.56	43.65	20: 71	10.47
24	Panicum obtusum	24	.....	Tex	...	10.95	2.25	46.44	33.12	7.24	1.16	.05	4.7	14.30	9.38	1.93	39.80	28.38	6.21
25	Panicum capillare	25	.....	Ind. T	..	5.59	3.89	55.30	28.24	6.98	1.12	.64	57.5	14.30	4.89	3.34	47.39	24.20	5.98
26	Panicum dichotomum	26	.....	Ala	....	10.13	3 55	50.07	29.48	6.77	1.08	.50	45.9	14.30	8.68	3.04	42.91	25.27	5.80
27	Setaria Italica	27	July 24	Pa	....	7.50	2.71	55.78	24.52	9.49	1.52	.51	33.6	14.30	6.43	2.32	47.80	21.02	8 13
28	Setaria glauca	28	July 24	D. C	....	7.27	2.66	55.28	25.76	9.04	1.44	.41	28.5	68.40	2.30	.84	17.47	8.13	2.86
29	..... do	29	Aug. 11	Pa	....	7.94	3.06	58.54	21.94	8.52	1.36	.39	28.7	14.30	6.80	2.62	50.18	18.80	7.30
30	Setaria setosa	30	.....	Tex	..	9.08	1.49	48.64	32.30	8.49	1.36	.56	41.1	14.30	7.78	1.28	41.68	27.68	7.28
31	Tripsacum dactyloides	31	.....	Miss	....	6.19	2.30	56.31	26.51	8.60	1.37	.38	27.6	14.30	5.30	2.05	48.26	22.72	7.37
32	..... do	32	Aug. 11	Pa	....	5.34	3.47	60.80	22.45	7.94	1.27	.32	25.2	14.30	4.58	2.97	52.11	19.24	6.80
33	Spartina cynosuroides	33	.....	Minn	....	7.22	3.42	53.76	25.79	9.81	1.57	.43	33.8	14.30	6.19	2.93	46.07	22.10	8.41
34	..... do	34	.....	Ill	....	6.55	2.96	61.12	22.89	6 48	1,04	.27	25.5	14.30	5,61	2.54	52,38	19.62	5.55

No. of analysis.		Specimen No.	Date cut.	Locality.	Height.	Dry substance.								Fresh substance or hay.					
						Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoid.	Per cent. of nitrogen non-albuminoid.	Water.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.
35	Spartina cynosuroides	35		Ind. T		5.20	3.40	59.32	27.20	4.88	.78	.45	57.5	14.30	4.46	2.91	50.84	23.31	4.18
36	Andropogon Virginicus	36		Tex		9.33	1.67	52.92	33.08	3.00	.48	.12	24.4	14.30	8.00	1.43	45.35	28.35	2.57
37	Andropogon scoparius	37		Ala		7.11	1.85	55.52	29.07	6.45	1.04	.26	24.7	14.30	6.09	1.59	47.58	24.91	5.53
38	do	38		Ala		5.84	1.58	62.29	24.64	5.65	2.90	1.64	56.6	14.30	5.00	1.35	53.39	21.12	4.84
39	do	39		Ind. T		4.46	3.19	58.37	29.84	4.14	.66	.39	59.7	14.30	3.82	2.73	50.03	25.57	3.55
40	Andropogon macrourus	40		Ala		3.74	2.54	58.20	29.75	5.77	.92	.58	57.1	14.30	3.21	2.18	49.87	25.50	4.94
41	Andropogon furcatus	41		D. C		5.09	3.02	58.19	25.65	8.05	1.29	.44	33.9	14.30	4.36	2.59	49.87	21.98	6.90
42	do	42		Nebr		7.86	2.10	58.46	26.26	5.32	.85	.32	37.5	14.30	6.74	1.80	50.10	22.50	4.56
43	do	43		Ind. T		4.08	3.19	57.60	31.18	3.95	.63	.33	52.5	14.30	3.50	2.73	49.36	26.72	3.39
44	do	44	Sept. 2	Pa		13.53	2.47	51.97	27.04	4.99	.80	.09	11.2	14.30	11.60	2.12	44.53	23.17	4.28
45	Andropogon argenteus	45		Ind. T		3.63	3.06	64.19	25.39	3.73	.60	.36	60.7	14.30	3.11	2.62	55.01	21.76	3.20
46	Sorghum halapense	46		Ala		8.07	2.84	52.24	25.05	11.80	1.89	.76	40.0	14.30	6.92	2.43	44.77	21.47	10.11
47	Sorghum nutans	47		Ind. T		5.21	2.54	59.75	28.62	3.88	.62	.33	52.5	14.30	4.46	2.18	51.21	24.53	3.32
48	do	48		Tex		9.17	1.63	50.32	35.68	3.20	.51	.21	41.2	14.30	7.86	1.40	43.12	30.58	2.74
49	Phalaris angusta	49		S. C		11.66	4.11	43.44	24.84	15.96	2.55	.....	.....	14.30	9.99	3.52	37.23	21.29	13 67
50	Anthoxanthum odoratum	50		N. H		8.43	3.41	53.81	25.79	8.56	1.37	.52	38.1	14.30	7.22	2.92	46.12	22.10	7.34
51	do	51	May 11-24	Pa		5.83	2.97	54.21	25.49	11.50	1.84	.66	35.9	14.30	5.00	2.54	46.46	21.85	9.85
52	do	52	May 1	D. C	15	7.09	3.36	59.45	26.63	9.47	1.52	.15	9.9	78.80	1.50	.71	12.61	4.37	2.01
53	Hierochloa borealis	53		Ill		9.82	4.06	49.45	28.02	14.15	2.27	.86	37.7	14.30	7.99	3.48	42.38	19.73	12.12
54	Alopecurus pratensis	54	May 1	D. C	60	7.75	3.36	54.30	23.78	10.81	1.73	.00	0.0	60.00	3.10	1.34	21.72	9.51	4.33
55	Aristida purpurascens	55		Ind. T		6.85	2.59	61.36	24.88	4.32	.69	.20	29.7	14.30	5.81	2.22	52.59	21.32	3.70
56	Milium effusum	56		Vt		9.28	3.87	46.33	24.55	15.97	2.64	.76	28.8	14.30	7.95	3.32	39.69	21.05	13.69
57	Muhlenbergia diffusa	57		Tex		9.28	1.81	55.35	23.56	10.00	1.60	.63	39.2	14.30	7.95	1.55	47.44	20.19	8.57
58	do	58	Aug. 25	Pa		16.40	3.43	47.35	21.94	10.88	1.74	.29	17.0	14.30	14.06	2.94	40.58	18.80	9.32
59	Muhlenbergia Mexicana	59	Aug. 23	Pa		4.33	2.09	65.47	22.69	4.82	.77	.18	23.4	14.30	3.71	2.30	56.11	19.45	4.13
60	Muhlenbergia glomerata	60		Minn		15.02	5.77	41.21	17.68	20.32	3.25	.93	28.5	14.30	12.87	4 94	35.32	15.15	17.42
61	Muhlenbergia sp. [?]	61		N. H		6.34	3.78	53.76	22.77	13.40	2.15	.80	37.2	14.30	5.43	3.20	46.07	19.52	11.48
62	Phleum pratense	62	June 18	D. C	58	5.66	3.58	58.93	21.93	9.90	1.58	.38	24.0	67.20	1.86	1.17	19.33	7.19	3.25
63	do	63	June 4	D. C	60	6.56	3.95	57.48	28.53	8.48	1.36	.30	22.0	63.40	2.40	1 45	21.04	8.01	3.10
64	do	64		D. C		7.16	4.47	50.03	27.35	10.99	1.75	.51	29.1	66.75	2.38	1.49	16.64	9.09	3.65
65	do	65	June 20	Pa		5.05	3.22	57.23	25.39	9.12	1.44	.41	28.5	14.30	4.33	2.77	49.06	21.72	7.82
66	do	66		N H		4.57	4.20	57.16	28.28	5.79	.93	.10	10.8	14.30	3.92	3.60	48.90	24.23	4.96
67	do	67		Ind		7.05	2.18	52.99	32.26	5.52	.88	.00	0.0	14.30	6.04	1.87	45.41	27.65	4.73
68	do	68	July 4, '92	Md		4.99	4.23	58.73	26.43	5.62	.90	.14	15.5	14.30	4.27	1.48	49.63	19.58	5.74
69	Sorghastrum nutans																		

71	....do	71	June 18	D. C	82	5.86	3.30	55.98	25.33	9.90	1.58	.80	50.7	14.30	5.90	2.84	46.77	21.71	8.48
72	....do	72	July 1	Pa	....	6.88	3.31	54.58	25.33	9.90	1.58	.80	50.7	14.30	5.90	2.84	46.77	21.71	8.48
73	....do	73	1882.	Del	....	6.53	3.54	56.80	21.68	11.25	1.80	.45	25.0	14.30	5.60	3.63	48.68	18.75	9.64
74	Agrostis exarata	74		Wis	....	5.95	2.30	56.63	24.51	10.61	1.70	.45	26.3	14.30	5.10	1.97	48.53	21.01	9.09
75	Cinna arundinacea	75		Ind. T	....	6.60	2.98	54.47	29.64	6.22	1.00	.47	47.4	14.30	5.73	2.55	46.60	25.40	5.33
76	Holcus lanatus	76	May 25	D. C	72	8.23	3.89	55.52	25.01	7.35	1.30	.60	46.2	50.60	4.07	1.92	27.43	12.35	3.63
77	Avena striata	77		Vt	....	4.96	4.00	56.13	26.16	8.75	1.40	.00	0.0	14.30	4.25	3.43	48.10	22.42	7.50
78	Arrhenatherum avenaceum	78	May 25	D. C	85	7.93	4.03	54.93	24.33	8.78	1.41	.15	10.6	62.30	2.99	1.52	20.71	9.17	3.31
79	....do	79	May 12	N. C	87	8.43	2.81	49.97	26.09	12.70	2.12	1.09	51.4	14.80	7.23	2.41	42.82	24.36	10.88
80	Danthonia spicata	80		N. H	...	4.38	3.80	56.92	29.11	5.79	.92	.29	31.1	14.30	3.75	3.26	48.78	24.95	4.96
81	Danthonia compressa	81		Vt	....	3.57	3.52	54.61	30.32	7.98	1.29	.30	22.9	14.30	3.06	3.02	46.80	25.98	6.84
82	Cynodon dactylon	82		Ala	....	9.11	1.57	52.61	23.29	13.42	2.15	.77	36.0	14.30	7.81	1.34	45.09	19.96	11.50
83	....do	83		Miss	....	9.91	2.13	53.75	23.52	10.69	1.71	1.01	59.2	14.30	8.49	1.83	46.06	20.16	9.16
84	Bonteloua oligostachya	84		D. C	....	7.81	3.12	57.84	22.65	8.58	1.37	.12	8.7	14.30	6.69	2.67	49.58	19.41	7.35
85	Eleusine Indica	85		Tex	....	19.24	2.14	34.01	31.01	13.60	2.18	1.14	52.2	14.30	16.49	1.83	29.15	26.58	11.65
86	....do	86		Ga	...	8.24	2.08	55.07	22.49	12.12	1.94	.75	38.7	14.30	7.06	1.78	47.20	19.27	10.39
87	....do	87		Ala	....	9.71	2.53	55.47	21.23	11.06	1.76	.81	46.3	14.30	8.32	2.17	47.54	18.19	9.48
88	Leptochloa mucronata	88		Tex	...	11.76	2.05	46.75	31.74	7.70	1.23	.59	47.8	14.30	10.08	1.76	40.06	27.20	6.60
89	Triodia purpurea	89		Ind. T	....	5.16	3.71	53.94	29.14	8.05	1.29	.62	48.0	14.30	4.42	3.18	46.23	24.97	6.90
90	Triodia sessleroides	90		Tex	....	5.13	1.99	48.86	37.72	6.30	1.01	.49	48.9	14.30	4.40	1.73	41.84	32.33	5.40
91	Uniola latifolia	91		Ala	....	14.64	3.12	34.13	37.24	10.87	1.74	.38	21.6	14.30	12.55	2.67	29.25	31.91	9.32
92	....do	92		Ind. T	....	10.42	2.49	55.95	24.66	6.48	1.04	.30	28.5	14.30	8.93	1.75	47.94	21.13	5.55
93	Dactylis glomerata	93		N. H	..	8.44	3.49	54.75	24.91	8.41	1.34	.35	30.9	14.30	7.23	2.99	46.92	21.35	7.21
94	....do	94	May 13	D. C	87	8.07	3.24	53.76	25.40	9.53	1.53	.16	10.5	77.30	1.83	0.74	12.20	5.77	2.16
95	....do	95	June 18	D. C	80	8.64	3.98	50.20	24.67	12.51	1.99	.77	38.7	66.90	2.86	1.32	16.62	8.16	4.14
96	....do	96	1880.	Pa	....	6.33	2.66	54.94	27.51	8.56	1.37	.51	37.2	14.30	5.42	2.28	47.08	23.58	7.34
97	.... do	97	1880.	N. C	....	7.42	3.56	56.03	23.08	9.91	1.58	.30	19.0	14.30	6.36	3.05	48.02	19.78	8.49
98	....do	98	1880.	N. C	....	8.90	3.68	52.16	24.97	10.29	1.61	.63	30.1	14.30	7.63	3.15	44.70	21.40	8.82
99	....do	99		Me	....	8.02	2.39	54.80	26.05	8.74	1.40	.36	25.7	14.30	6.87	2.05	46.96	22.33	7.49
100	Poa pratensis	100		Wis	....	5.20	2.86	52.46	27.94	11.54	1.85	.50	26.8	14.30	4.46	2.45	44.96	23.94	9.89
101	....do	101		N. H	....	5.47	4.95	59.61	22.47	7.50	1.20	.36	30.3	14.30	4.69	4.24	57.08	19.26	6.43
102	....do	102	May 21	D. C	70	8.30	3.90	51.43	23.76	12.61	2.01	.02	1.0	71.90	2.33	1.10	14.45	6.68	3.54
103	....do	103	May 8	D. C	65	7.02	2.85	56.85	25.46	7.82	1.28	.10	7.8	69.00	2.18	0.88	17.62	7.89	2.43
104	.... do	104	May 19	D. C	70	7.73	3.41	55.32	23.10	10.44	1.67	.14	.84	66.20	2.61	1.15	18.70	7.81	3.53
105	....do	105	May 17	Ill	....	7.82	3.77	48.39	24.93	15.09	2.41	.51	21.1	14.30	6.70	3.23	41.47	21.36	12.94
106	....do	106	June 16	N. C	....	9.01	4.35	47.95	24.13	14.56	2.33	.45	19.3	14.30	7.72	3.73	41.09	20.68	12.48
107	....do	107	May 26	Pa	....	7.48	4.58	53.08	20.64	14.22	2.27	.47	20.8	14.30	6.41	3.93	45.48	17.69	12.19
108	Poa compressa	108		N. H	....	5.21	3.44	57.18	25.35	8.82	1.41	.36	25.2	14.30	4.46	2.95	49.00	21.73	7.56
109	....do	109	June 17	D. C	30	6.08	4.52	58.18	18.53	12.69	2.03	.45	22.2	70.70	1.78	1.32	17.05	5.43	3.72
110	....do	110	June 10	Pa	....	7.85	3.84	58.47	20.90	8.94	1.43	.38	26.9	14.30	6.73	3.29	50.11	17.91	7.66
111	....do	111	June 6	Del	....	6.54	4.25	55.61	20.15	13.45	2.15	.53	24.5	14.30	5.60	3.64	47.66	17.27	11.53
112	Poa serotina	112		Wis	..	4.23	2.84	65.81	20.85	6.27	1.01	.33	32.6	14.30	3.63	2.43	56.40	17.87	5.37
113	Poa arachnifera	113		Tex	...	11.62	3.71	42.16	31.89	10.61	1.70	.....	.....	14.30	9.96	3.18	36.13	27.33	9.10
114	Poa alsodes	114	June 2	Pa	....	9.41	4.09	51.41	21.25	13.84	2.21	.32	14.5	14.30	8.06	3.51	44.06	18.21	11.86
115	Glyceria aquatica	115		Vt	....	7.30	2.20	56.77	25.60	8.13	1.30	.30	22.7	14.30	6.26	1.89	48.64	21.94	6.97
116	Glyceria nervata	116		Vt	....	6.19	3.20	53.00	28.20	9.41	1.50	.33	22.1	14.30	5.30	2.74	45.43	24.17	8.06
117	....do	117		N. H	....	6.80	2.91	60.01	21.97	8.31	1.31	.45	34.1	14.30	5.83	2.49	51.43	18.83	7.12
118	....do	118	June 2	Pa	....	7.93	2.87	53.01	21.38	14.81	2.37	.58	24.6	14.30	6.79	2.46	45.43	18.32	12.70
119	Festuca ovina	119		N. H	....	5.03	4.26	84.18	.....	6.53	1.04	.....	.....	14.30	4.31	3.65	72.14	.....	5.60
120	....do	120	May 21	D. C	40	5.60	2.51	58.20	23.79	9.90	1.52	.16	10.5	67.00	1.85	0.83	19.21	7.85	3.26

No. of analysis.		Specimen No.	Date cut.	Locality.	Height.	Dry substance.						Fresh substance or hay.							
						Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoid.	Per cent. of nitrogen as non-albuminoid.	Water.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.
121	Festuca elatior	121	June 2	Pa		8.07	4.07	51.59	22.50	13 77	2.20	.77	35.0	14.30	6.91	3.48	44.22	19.29	11.80
122	Festuca pratensis	122		N. H		9.13	3.28	52.59	24.25	10.75	1.72	.77	44.9	14.30	7.83	2.81	45.07	20.78	9.21
123	do	123	June 1	D. C	76	7.16	3.30	50.54	27.63	11.37	1.82	.79	43.5	14.30	6.14	2.83	43.31	23.68	9.74
124	Bromus secalinus	124		N. H		7.12	4.08	57.30	23.79	7.71	1.23	.57	46.4	14.30	6.10	3.49	49.11	20.39	6.61
125	Bromus unioloides	125		D. C		9.74	3.58	52.47	20.59	13.62	2.18	.96	44.2	14.30	8.35	3.07	44.97	17.64	11.67
126	do	126	May 13	D. C	76	9.26	3.96	51.46	22.69	12.63	2.02	.34	16.8	79.40	1.91	.82	10.60	4.67	2.60
127	Bromus erectus	127	May 19	D. C	68	7.70	2.81	56.19	24.52	8.78	1.41	.34	24.1	63.70	2.79	1.02	20.40	8.90	3.19
128	Bromus carinatus	128		Ill		10.88	2.68	49.79	26.73	9.92	1.59	.34	21.2	14.30	9.32	2.30	42.67	22.91	8.50
129	Lolium perenne	129	June 1	D. C	52	7.50	2.64	56.84	25.42	7.60	1.21	.....	.....	63.10	2.77	.97	20.97	9.30	2.81
130	do	130	May 26	Pa		6.09	2.84	63.94	18.26	8.87	1.42	.47	33.1	14.30	5.22	2.43	54.80	15.65	7.60
131	Lolium Italicum	131	May 26	D. C	90	11.02	2.32	51.73	20.44	14.49	2.32	.18	7.8	78.00	2.42	0.51	11.39	4.50	3.18
132	Agropyrum repens	132		N. H		9.32	3.52	56.27	19.41	11.48	1.84	.45	24.5	14.30	7.99	3.02	48.22	16.63	9.84
133	do	133	June 12	Pa		6.23	3.51	57.75	24.08	8.43	1.35	.62	45.9	14.30	5.34	3.00	49.50	20.64	7.22
134	do	134		Me		7.28	3 83	50.95	25.30	12.64	2.02	.60	29 7	14.30	6.25	3 28	43.66	21.68	10.83
135	do	135	June 23	D. C		8.77	3.36	59.37	19.70	8.80	1.41	.26	18.7	58.30	3.65	1.40	24.76	8.22	3.67
136	Elymus Canadensis	136		Ind. T		5.99	3.71	50.78	34.66	4.86	.77	.30	38.3	14.30	5.87	2.22	52.59	21.32	3.70

The great variation in composition of grasses becomes apparent on examining the one hundred and thirty-six analyses; and by selecting the highest and lowest determinations the following table of extremes has been prepared:

Limits of composition of grasses.

Dry substance.	Highest.	Lowest.
Ash	19.24	3.57
Fat	5.77	1.48
Nitrogen free extract	66.01	34.01
Crude fiber	37.72	17.68
Albuminoids	23.13	2.80
Nitrogen	3.70	.45
Non-albuminoid nitrogen	1.64	.00
Per cent. of nitrogen as non-albuminoid	60.7	.00
Water in fresh grass	76.50	60.00

The highest ash is undoubtedly owing to the presence of adherent soil, and the lowest carbo-hydrates are dependent relatively on the same cause. The wide variations in fiber and albuminoids must be regarded, however, as being entirely due to physiological causes, which are difficult to explain. *Digitaria sanguinale*, for instance, which in one specimen contains the extreme amount of albuminoids and a small amount of fiber has in another only half as much albumen and one and three-quarter times as much fiber. We learn, then, that species are not in themselves at all fixed in their composition, there being as large variations among specimens of the same as between specimens of different species. Examples may be found in several portions of the preceding tables, and, for illustration, several analyses of *Phelum pratense* and of *Dactylis glomerata* from widely separated localities are given in the following tables:

Analyses of Phleum pratense (timothy) from various localities.

FULL BLOOM.

Locality.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoids nitrogen.	Per cent. of total nitrogen as non-albuminoids.
Department garden, 1881	7.16	4.47	50.03	27.35	10.99	1.75	.51	29.1
Department garden, 1880	5.66	3.58	58.93	21.93	9.90	1.58	.38	24.0
Maryland	4.93	4.22	52.83	30.43	7.69	1.23	.15	12.2
New Hampshire	4.57	4.20	57.16	28.28	5.79	.93	.10	10.8
Indiana	7.05	2.18	52.99	32.26	5.52	.88	.00	.0

Analyses of Dactylis glomerata (orchard grass) from various localities.

FULL BLOOM.

Locality.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoids nitrogen.	Per cent. of total nitrogen as non-albuminoids.
North Carolina	7.42	3.56	56.03	23.08	9.91	1.58	.30	19.0
District of Columbia	8.07	3.24	53.76	25.40	9.53	1.53	.16	10.5
Maine	8.02	3.39	54.80	26.05	8.74	1.40	.36	25.7
District of Columbia	6.00	3.62	57.34	24.42	8.62	1.38	.42	30.4
Pennsylvania	6.33	2.66	54.99	27,51	8.56	1.37	.51	37.2
New Hampshire	8.44	3.49	54.75	24.91	8.41	1.35	.42	30.9

AVERAGE.

Five Localities.	7.38	3.33	55.17	25.19	8.91	1.43	.36	25.2

The average composition of American grasses as derived from the preceding analyses of grasses in bloom and averages for different sections of the country, has been calculated. The results presented in the following table, with Wolff's averages for German grasses, are of interest:

Average composition of grasses.

	Number of analyses.	Ash.	Fat.	Nitrogen free extraction.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoid nitrogen.	Per cent of total as non-albuminoids.
American:									
United States	135	7.97	3.14	53.97	23.71	9.21	1.47	.45	30.6
North of Potomac	70	7.64	3.44	55.01	23.70	10.21	1.63	.32	19.6
South	27	8.80	2.74	52.55	26.68	9.23	1.47	.56	38.1
Middle West	8	7.12	2.96	54.58	25.39	9.95	1.60	.41	25.6
West of Mississippi	39	8.23	2.86	52.67	29.60	6.64	1.06	.41	38.7
German (Wolff):									
Fair	.....	6.30	2.34	46.53	34.09	10.74	1.72	.....	.....
Good	.....	7.23	2.92	47.84	30.69	11.32	1.81	.....	.....
Very good	.....	8.24	3.29	48.93	25.77	13.77	2.20	.....	.....

The different sections furnish very different qualities of grasses, and for the reason that those from the North were almost entirely from cultivated soil, while those from the other sections were many or most of them wild species from old sod. The improvement brought about by cultivation is marked and the difference between a ton of wild Western and Eastern cultivated hay is apparent.

In comparison with German grasses our best do not equal in amount of albuminoids those classed by Wolff as *fair*, but they are far superior in having a much smaller percentage of fiber and consequently a larger

amount of digestible carbo-hydrates. In the grasses of both countries the fiber increases with regularity as the nitrogenous constitutents decrease, and of the latter the non-albuminoid portion is relatively greatly the poorer the quality of the grass.

CHANGES IN COMPOSITION DURING GROWTH.

In addition to the single analysis previously tabulated, analyses have been made of series illustrating the changes in composition of several species from the appearance of the blade to the maturity of the seed.

The grasses examined comprise:

I. *Agrostis vulgaris.* (Red top.)
- A series from richer soil.
- A series from poorer soil.

II. *Phleum pratense.* (Timothy.)
- A series from richer soil.
- A series from poorer soil.
- A series of first year's growth from seed sown in garden soil.
- A series from La Fayette, Ind.
- A series from Hanover, N. H., the two latter from rather poor soil.

III. *Dactylis, glomerata.* (Orchard grass.)
- A series from the first growth.
- A series from later growth.

IV. *Alopecurus pratensis.* (Meadow fox-tail.)
- A series from good sod.

V. *Poa pratensis.* (Blue grass, Meadow grass.)
- A series from good soil.
- A series from poorer soil.
- A series from the wayside.
- A series from Quincy, Ill.

VI. *Poa compressa.* (Wire grass.)
- A series from poor soil.

VII. *Bromus unioloides.* (Schrader's grass.)
- A series from rich garden soil.

VIII. *Bromus erectus.* (Broom grass.)
- A series from poor soil.

IX. *Holcus lanatus.* (Satin grass.)
- A series from poor soil.

X. *Arrhenatherum avenaceum.*
- A series from medium soil.

XI. *Setaria glauca.*
- A series from medium soil.

XII. *Anthoxanthum odoratum.* (Sweet vernal grass.)
- A series from medium soil.

XIII. *Festuca ovina.* (Sheep's fescue.)
- A series from poor soil, growing in bunches.

XIV. *Lolium Italicum.* (Italian Rye grass.)
- A series from low moist soil.
- A series of first year's growth from the seed in garden soil.

XV. *Lolium perenne.* (Rye grass darnel.)
- A series from medium soil.

With a few exceptions the specimens were personally collected in the grounds of the Department, and are to be so understood when nothing else is said in their description. They all grew in the summer of 1889 except the few series illustrative of the first year's growth of certain species. The character of the soils has been designated as rich or garden soil, good soil, poorer soil, and wayside soil. The first is that of the experimental garden of the Department, and is above the average richness of cultivated soils; the second is that of the lawns about the Department building, the third, a light gravelly soil, occurring in a portion of the grounds, and the last the gutters and paths.

The specimens were cut close to the roots, weighed and dried rapidly in a current of air at 60° C. The methods of analysis were such as have been described in previous reports.

	When cut.	Height in centimeters.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoid nitrogen.	Per cent. of nitrogen non-albuminoid.	Water.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.
I.—AGROTIS VULGARIS.																
DEPARTMENT GROUNDS.																
Good soil:																
Panicle not out	June 1	42	8.19	3.77	53.88	20.97	13.19	2.11	.82	38.9	67.8	2.64	1.21	17.85	6.75	4.25
Panicle out; closed	June 1	58	7.34	4.05	54.13	20.87	13.61	2.18	.80	36.7	68.1	2.34	1.29	17.27	6.66	4.34
In early bloom	June 19	48	7.55	3.62	54.46	21.64	12.73	2.04	.54	26.4	70.1	2.25	1.08	16.29	6.47	3.81
In full bloom	June 23	45	7.27	2.87	56.82	22.02	11.02	1.76	.53	30.1	61.4	2.80	1.11	21.94	8.50	4.25
Seed in the milk	July 1	43	6.60	3.51	60.02	19.43	10.44	1.67	.36	21.6	53.3	3.08	1.64	28.03	9.07	4.88
Seed hard	July 1	47	6.74	4.25	58.88	20.66	9.47	1.52	.18	11.8	51.5	3.27	2.06	28.56	10.02	4.59
Seed mature	July 9	55	5.30	2.74	61.32	21.75	8.89	1.42	.09	6.3	57.0	2.28	1.18	26.37	9.35	3.82
Poorer soil:																
Panicle spreading	June 16	43	8.41	3.88	57.41	20.49	9.81	1.57	.28	17.8	68.2	2.67	1.23	18.26	6.52	3.12
Early blooming	June 18	53	5.84	5.30	58.49	20.44	9.95	1.59	.32	20.1	58.8	2.41	2.18	24.10	8.41	4.10
II.—PHLEUM PRATENSE.																
DEPARTMENT GROUNDS.																
Good soil:																
Spike invisible	June 1	42	8.68	4.56	54.31	19.91	12.54	2.01	1.70	35.0	70.7	2.54	1.34	15.92	5.83	3.67
Spike visible	June 1	62	6.41	3.40	57.26	21.03	11.90	1.86	.55	29.5	71.9	1.80	.96	16.09	5.91	3.34
Before bloom	June 23	45	9.82	3.63	54.19	22.03	10.33	1.65	.36	21.8	67.5	3.19	1.18	17.61	7.16	3.36
In early bloom	June 23	60	6.04	3.85	57.21	22.70	10.20	1.63	.30	18.4	64.9	2.12	1.35	20.08	7.97	3.58
In full bloom	June 18	58	5.66	3.58	58.93	21.93	9.90	1.58	.38	24.0	67.2	1.86	1.17	19.33	7.19	3.25
Early seed	June 18	52	10.53	3.40	51.07	22.90	12.10	1.93	.51	26.4	77.8	2.34	.76	11.34	5.08	2.68
Poorer soil:																
In bloom	June 4	60	6.56	3.95	57.48	23.53	8.48	1.36	.30	22.0	68.4	2.40	1.45	21.04	8.61	3.10
In full bloom	July 1	70	5.64	2.98	61.08	22.84	7.46	1.19	.36	30.3	71.9	1.58	.84	17.16	6.42	2.10
DEPARTMENT GARDEN.																
First year's growth:																
Head out	June 19	49	8.58	6.10	47.22	23.95	14.15	2.26	.39	17.3	78.56	1.84	1.31	10.12	5.14	3.03
In bloom	June 26	76	7.16	4.47	50.03	27.35	10.99	1.75	.51	29.1	66.75	2.38	1.49	16.64	9.09	3.65
After bloom	July 3	65	6.52	4.69	51.79	28.26	8.74	1.40	.25	17.9	56.63	2.83	2.03	22.46	12.26	3.79
Do	July 10	75	5.63	3.72	55.39	27.08	8.18	1.27	.15	11.3	58.86	2.31	1.53	22.79	11.14	3.37

	When cut.	Height in centimeters.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoid nitrogen.	Per cent. of nitrogen non-albuminoid.	Water.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.
II.—PHLEUM PRATENSE—Continued.																
INDIANA.																
Head not out	June 8	....	7.94	1.97	49.93	29.19	10.97	1.75	.18	10.3	70.00	2.38	.59	14.98	8.76	3.26
Before bloom	June 15	....	7.64	2.27	52.64	29.65	7.80	1.25	.28	22.4	67.50	2.48	.74	17.11	9.64	2.53
In bloom	June 26	....	7.05	2.18	52.99	32.26	5.52	.88	.00	.00	64.50	2.50	.78	18.81	11.45	1.96
After bloom	July 6	....	6.63	2.55	53.93	31.32	5.57	.89	.03	3.3	56.30	2.90	1.11	23.57	13.69	2.43
Early seed	July 16	....	5.95	3.74	60.77	24.70	4.84	.78	.00	.00	53.00	2.80	1.76	28.56	11.61	2.27
NEW HAMPSHIRE.																
Spike invisible		....	5.19	4.60	57.09	23.46	7.66	1.55	.30	19.4						
Spike visible		....	4.73	4.22	56.10	25.34	9.61	1.54	.45	29.2						
In bloom		....	4.57	4.20	57.16	28.28	5.79	.93	.10	10.8						
After bloom		....	3.88	3.23	58.72	28.92	5.25	.84	.15	17.9						
Early seed		....	3.2	2.7	62.5	26.03	5.41	.87	.18	20.7						
III.—DACTYLIS GLOMERATA.																
DEPARTMENT GARDEN.																
Panicles not out	Apr. 23	35	10.29	4.12	50.86	18.76	15.97	2.49	1.01	40.6	78.8	2.18	.87	10.78	3.98	3.39
Panicles closed	May 4	55	8.26	3.13	55.04	23.18	10.39	1.63	*.00	0.0	79.3	1.71	.64	11.40	4.80	2.15
In full bloom	May 13	87	8.07	3.24	53.76	25.40	9.53	1.53	.16	10.5	77.3	1.83	.74	12.20	5.77	2.16
After bloom	June 1	125	9.01	2.83	52.65	27.26	8.25	1.32	.33	25.0	73.5	2.39	.75	13.95	7.22	2.19
Later growth:																
In bloom	June 18	80	8.64	3.98	50.20	24.67	12.51	1.99	.77	38.7	66.9	2.86	1.32	16.62	8.16	4.14
Late bloom	June 23	75	6.00	3.62	57.34	24.42	8.62	1.38	.42	30.4	60.2	2.39	1.44	22.82	9.72	3.43
Seed nearly ripe	July 1	75	6.73	3.34	57.54	25.09	7.30	1.16	.45	38.8	62.3	2.54	1.26	21.69	9.46	2.75
DEPARTMENT GARDEN.																
First year's growth:																
Head not out	June 12	28	11.50	6.89	48.06	20.63	12.92	2.07	.15	7.3	79.50	2.36	1.41	9.85	4.23	2.65
Green	July 15	...	10.52	6.56	46.05	21.64	14.03	2.25	.39	17.3	72.30	3.01	1.90	13.00	6.00	3.89
Yellow	July 15	....	10.14	5.95	52.37	22.44	9.10	1.46	.18	12.3	74.60	2.58	1.51	13.30	5.70	2.31
	Oct. 25	.....	10.95	6.50	47.98	21.24	13.33	2.14	.54	25.2	65.70	3.43	2.03	10.02	6.05	4.17

IV.—ALOPECURUS PRATENSE.															
Head just appearing	Apr. 19	....	9.21	4.69	52.16	18.21	15.73	2.52	.66	38.2	77.1	2.11	1.08	11.94	4.17	3.60
Before bloom	Apr. 19	..	7.90	4.46	51.66	22.40	13.58	2.17	.53	40.9	76.7	1.84	1.04	12.03	5.22	3.17
In bloom	May 1	....	7.75	3.36	54.30	23.78	10.81	1.73	.00	0.0	60.0	3.10	1.34	21.73	9.51	4.32
After bloom	May 12	....	8.17	3.50	54.35	25.36	8.62	1.38	.07	5.0	66.6	2.73	1.17	18.15	8.47	2.88
V.—POA PRATENSIS.															
DEPARTMENT GARDEN.															
Set No. 1 grown on good soil:															
Panicle just visible	Apr. 23	20	8.07	4.88	48.74	18.43	19.88	3.18	.48	15.1	76.70	1.88	1.14	11.34	4.30	4.64
Panicle spreading	May 1	30	5.51	4.07	51.32	22.83	16.21	2.68	.30	11.2	70.80	1.61	1.19	14.99	6.67	4.74
In full bloom	May 21	70	8.30	3.90	51.43	23.76	12.61	2.01	.02	1.0	71.90	2.33	1.10	14.45	6.68	3.54
In seed	June 5	70	6.38	4.25	52.54	24.34	12.49	2.00	.37	18.5	55.90	2.81	1.87	23.17	10.74	5.51
Set No. 2 grown on poor soil:															
Panicle closed	Apr. 27	...	6.61	3.92	55.32	21.92	12.23	1.96	.12	6.1	.....	.....	.....	.....	.....	.....
In full bloom	May 8	65	7.02	2.85	56.85	25.46	7.82	1.28	.10	7.8	69.00	2.18	.88	17.62	7.90	2.42
Set No. 3 grown on poor soil; wayside:															
After bloom; brown	June 1	6.	7.23	3.92	56.12	23.85	8.88	1.42	.25	17.6	55.40	3.22	1.75	25.03	10.64	3.96
In full bloom	May 19	78	7.73	3.41	55.32	23.10	10.44	1.67	.14	8.4	66.20	2.62	1.15	18.69	7.81	3.53
In seed; brown	June 8	75	6.21	3.51	58.58	24.34	7.36	1.18	.15	12.7	54.60	2.81	1.59	26.61	11.05	3.34
QUINCY, ILL.															
Set No. 4:															
Before bloom	May 10	....	8.42	4.99	45.34	21.87	19.38	3.10	.63	20.3	.....	.....	.....	.....	.....	.....
In bloom	May 17	...	7.82	3.77	48.39	24.93	15.09	2.41	.51	21.1	.....	.....	.....	.....	.....	.....
After bloom	May 27	....	9.07	3.30	52.51	22.75	12.37	1.97	.35	17.8	.....	.....	.....	.....	.....	.....
VI.—POA COMPRESSA.															
Poor soil:															
Panicle not out	June 1	14	7.75	5.29	58.08	18.19	10.69	1.71	.10	5.8	67.90	2.49	1.70	18.64	5.84	3.43
Panicle well out	June 1	28	6.81	4.41	55.18	21.30	12.30	1.97	.52	26.4	68.70	2.13	1.38	17.27	6.67	3.85
In bloom	June 17	30	6.08	4.52	58.18	18.53	12.69	2.03	.45	22.2	70.70	1.78	1.32	17.05	5.43	3.72
After bloom	June 23	30	5.13	3.85	63.89	18.16	8.97	1.43	.35	24.5	51.80	2.47	1.86	30.79	8.75	4.33
VII.—BROMUS UNIOLOIDES.															
Panicle not out	Apr. 23	35	10.65	5.03	48.73	18.54	17.05	2.73	1.06	38.8	80.60	2.07	.97	9.45	3.60	3.31
Panicle closed	May 4	64	8.95	3.44	51.03	22.22	14.36	2.31	.55	23.8	75.40	2.20	.85	12.55	5.47	3.53
In full bloom	May 13	76	9.26	3.96	51.46	22.69	12.63	2.02	.34	16.8	79.40	1.91	.82	10.60	4.67	2.60
After bloom	June 1	76	6.68	2.37	54.79	25.33	10.83	1.74	.35	20.1	67.50	2.17	.77	17.80	8.23	3.52
In seed; brown	June 1	85	8.55	2.10	50.71	19.85	9.79	1.57	.33	21.0	64.70	3.02	.74	21.08	7.01	3.45
VIII.—BROMUS ERECTUS.															
Very young	Apr. 27	35	8.63	3.67	45.27	26.65	15.78	2.52	.43	17.1	85.50	1.25	.53	6.57	3.87	2.28
Before bloom	May 8	60	7.26	3.27	52.01	25.24	12.22	1.95	.24	12.3	74.30	1.86	.84	13.37	6.49	3.14
Do	May 12	68	7.40	3.72	53.38	24.48	11.02	1.76	.09	5.1	72.20	2.06	1.03	14.84	6.81	3.06

	When cut.	Height in centimeters.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.	Total nitrogen.	Non-albuminoid nitrogen.	Per cent. of nitrogen non-albuminoid	Water.	Ash.	Fat.	Nitrogen free extract.	Crude fiber.	Albuminoids.
VIII.—BROMUS ERECTUS—Continued.																
Early bloom	May 19	68	7.70	2.81	56.19	24.52	8.78	1.41	.34	24.1	63.70	2.79	1.02	20.40	8.90	3.19
After bloom	June 1	75	8.51	2.92	56.32	23.64	8.61	1.38	.40	29.0						
IX.—HOLCUS LANATUS.																
Very young	Apr. 2	..	9.98	4.53	54.48	18.64	12.37	1.98	.21	10.6	82.3	1.77	.80	9.64	3.30	2.19
Late bloom	May 25	72	8.23	3.89	55.52	25.01	7.35	1.30	.60	46.2	50.6	4.07	1.92	27.43	12.35	3.63
X.—ARRHENATHERUM AVENACEUM.																
In full bloom	May 25	85	7.93	4.03	54.93	24.33	8.78	1.41	.15	10.6	62.3	2.99	1.52	20.71	9.17	3.31
In after bloom	June 4	60	7.88	4.19	51.76	21.51	14.66	2.35	.96	40.9	74.4	2.02	1.07	13.25	5.51	3.75
XI.—SETARIA GLAUCA.																
Very young	July 1	50	10.84	2.34	48.12	21.68	17.02	2.72	1.00	36.8	74.2	2.80	.60	12.42	5.59	4.39
Early flowering	July 24	80	7.27	2.66	55.28	25.75	9.04	1.44	.41	28.5	68.4	2.29	.84	17.47	8.14	2.86
XII.—ANTHOXANTHUM ODORATUM.																
Very young	May 1	15	6.39	4.27	61.58	17.17	10.59	1.70	.06	3.5	76.9	1.47	.99	14.22	3.97	2.45
In full bloom	May 1	40	7.09	3.36	59.45	20.63	9.47	1.52	.15	9.9	78.8	1.50	.71	12.62	4.37	2.00
After bloom	June 19	45	7.27	4.86	53.40	21.17	13.30	2.13	.51	23.9	69.9	2.20	1.46	16.07	6.37	4.00
After blooming	July 19	55	5.79	4.08	58.02	25.00	7.11	1.14	.35	30.7	53.4	2.70	1.90	27.04	11.65	3.31
XIII.—FESTUCA OVINA.																
Very young	Apr. 27	25	6.47	4.31	54.00	20.31	14.91	2.38	.12	5.0	70.0	1.94	1.29	16.21	6.09	4.47
Before bloom	May 8	36	5.41	3.61	57.13	25.10	8.75	1.40	.06	4.3	65.4	1.87	1.25	19.76	8.69	3.03
Do	May 12	45	6.00	3.43	55.44	25.65	9.48	1.52	.16	10.5	67.0	1.98	1.13	18.29	8.47	3.13
In bloom	May 21	40	5.60	2.51	58.20	23.79	9.90	1.58	.27	17.1	58.7	2.59	1.16	26.95	11.02	4.58
After bloom	June 1	47	6.57	3.07	57.09	23.96	9.31	1.49	.27	18.1	53.9	3.03	1.41	26.32	11.05	4.29
XIV.—LOLIUM ITALICUM																
Heads invisible	Apr. 27	55	13.28	4.00	43.04	18.15	21.64	3.46	.07	19.9	82.3	2.35	.86	7.45	3.28	3.81

XIV.—Lolium Italicum—Continued.															
Heads just out	May 21	75	11.89	3.81	48.74	21.75	14.81	2.29	.39	17.0	82.7	1.97	.66	8.43	3.76	2.48
In full bloom	May 26	90	11.02	2.82	51.78	20.44	14.49	2.32	.18	7.8	78.0	2.42	.51	11.39	4.49	3.19
After bloom	June 4	92	8.76	3.98	53.81	21.86	11.59	1.85	.43	23.2	71.5	2.50	1.13	15.34	6.23	3.30
First year's growth:																
Head not out	June 2	22	13.24	6.91	45.55	15.50	18.80	3.01	.60	19.9	84.00	2.12	1.10	7.79	2.48	3.01
Do	June 12	31	12.70	6.36	49.69	16.99	14.26	2.28	.45	19.7	82.70	2.20	1.10	8.59	2.94	2.47
Do	June 19	38	14.06	6.18	45.07	17.84	16.85	2.69	.66	24.6	82.30	2.49	1.09	7.98	3.16	2.98
Do	July 10	....	13.87	6.53	44.50	20.65	14.45	2.31	.59	25.5	78.90	2.82	1.38	9.39	4.36	3.05
Do	Oct. 25	25	10.87	5.31	47.82	22.40	13.60	2.17	.49	22.6	71.60	3.09	1.51	13.58	6.36	3.86
XV.—Lolium perenne.																
Head invisible	May 1	35	8.66	3.58	57.70	18.39	11.67	1.87	.28	15.0	78.6	1.85	.76	12.35	3.94	2.50
Do	May 4	28	9.48	4.84	55.08	18.00	13.10	2.09	.39	18.7	82.4	1.67	.76	9.69	3.17	2.31
Head well out	May 4	30	7.96	3.64	56.75	20.55	11.10	1.78	.33	18.5	74.0	2.07	.94	14.71	5.34	2.89
Before bloom	May 12	55	8.40	3.75	54.93	23.93	8.99	1.43	.09	6.3	76.4	1.98	.89	12.96	5.65	2.12
After bloom	June 1	52	7.50	2.64	56.84	25.42	7.60	1.21	.....	.....	63.1	2.77	.97	20.97	9.38	2.81

The preceding analyses furnish the data from which is derived the general conclusion that as a grass grows older its content of water decreases, ash decreases, fat decreases, albuminoids decrease, carbo-hydrates increase, crude fiber increases, non-albuminnoids decrease till bloom or slightly after, when it is at its lowest, and then increases again during the formation of the seed.

There are exceptions to these rules, but for the large majority of species under ordinary conditions of environment they hold good.

There are almost no exceptions to the fact that the water decreases in the maturer specimens; that is to say, the plant gradually dries up and becomes less succulent. The ash is very dependent on locality and surroundings, and as in the analyses which are here published it includes whatever soil there may be mechanically adherent to the blade or stalk as collected, it sometimes shows irregularities from one period to another.

The albuminoids decrease in amount with great regularity, the few cases where an increase appears being owing to the fact that the specimens were probably grown under varying conditions.

The fiber sometimes decreases, as in *Bromus erectus*, but the change in that direction is never large.

The non-albuminoid constituents, however, are often quite the reverse of constant in their manner of appearance and disappearance, and show themselves to be largely or more affected by environment than any other constituent. In *Agrostis vulgaris* they continue to decrease after bloom, and in *Anthoxanthum odoratum* and *Festuca ovina* they increase steadily from early growth to maturity. The relative amount present in the same species from different localities is extremely variable, as may be seen in the analyses of *Phleum pratense*, where specimens from Indiana contain almost no non-albuminoid nitrogen, while those from the District of Columbia and elsewhere are well supplied. The specimens from poorer soil having the smallest amount in some cases and the largest in others, the fact can hardly be due directly and entirely to the lack of cultivation, but as the *averages* show that the best grasses contain the least non-albuminoids it is plain that it is dependent on the sources of nitrogen and the supply furnished the plant. The usual changes in the non-albuminoids seem to point to the possibility that they increase at the time of the formation of the seed in the act of transferring to the seed as amides, the nitrogen of the plant.

THE BEST PERIOD OF GROWTH AT WHICH TO CUT FOR HAY.

Although largely a matter of opinion, it would seem from the foregoing results that the time of bloom or very little later is the fittest for cutting grasses to be cured as hay. The amount of water has diminished relatively, and there is a proportionately larger amount of nutriment in the material cut, and the weight of the latter will be at its highest point economically considered. Later on, the amount of fiber becomes too prominent, the stalk grows hard, arid, indigestible, and the

albuminoids decrease, while the dry seeds are readily detached from their glumes and lost with their store of nitrogen.

For different species, however, different times are undoubtedly suitable, and experience must be added to our chemical knowledge to enable a rational decision to be arrived at.

THE COMPOSITION OF THE ASH.

The ash of many foreign varieties of grasses have been analyzed and the results collected and published by Wolff. Of American growth the ash of only a number of the wild grasses collected in 1878 have been examined. The results are here given:

Ash analyses—grasses.

Name.	Phosphoric acid, P_2O_5.	Sulphuric acid, SO_3.	Silica, SiO_2.	Chlorine, Cl.	Calcium oxide, CaO.	Magnesium oxide, MgO.	Pot. oxide, K_2O.	Potassium, K.	Sod. oxide, Na_2O.	Sodium, Na.
Hierochloa borealis (Vanilla grass)	7.42	2.55	42.73	4.49	3.97	2.54	31.51	4.54	.....	.25
Eleusine Indica (wire grass)	2.69	4.24	47.56	10.09	10.27	4.10	10.27	9.52	.....	1.26
Eleusine India (wire grass)	9.68	5.79	24.61	6.71	13.65	7.38	24.79	7.39	.....	.....
Eleusine India (wire grass)	9.84	8.55	16.25	9.61	11.10	5.57	30.98	4.55	.....	3.55
Uniola latifolia (fescue grass)	4.92	2.62	66.87	4.71	7.15	3.02	5.52	5.19	.....	.....
Cynodon dactylon (Bermuda grass)	6.20	9.37	30.29	6.05	13.44	5.00	22.99	6.66	.....	.....
Cynodon dactylon (Bermuda grass)	5.09	11.31	30.27	9.46	7.99	2.96	22.89	9.61	.....	.42
Sporobolus Indicus (smut grass)	6.02	4.60	27.36	11.03	2.64	2.66	33.53	12.16	.....	.....
Andropogon Virg. (broom grass)	2.97	2.80	58.33	6.37	6.76	1.83	13.93	7.01	.....	.....
Andropogon scoparius	1.33	trace	64.62	15.65	2.12	.58	.....	15.70	.....	.....
Poa pratensis (Kentucky blue grass)	9.88	4.76	30.25	6.30	4.81	3.23	33.81	6.95	.....	.....
Poa serotina (fowl meadow grass)	10.80	3.35	37.10	3.80	6.70	2.92	31.71	2.79	.....	.83
Dactyloctenium Egypt (Egyptian grass)	8.37	4.42	34.17	6.76	20.67	6.91	21.20	7.50	.....	.....
Panicum sanguinale (Crab grass)	6.40	4.02	30.93	6.04	4.40	7.98	33.56	6.67	.....	.....
Panicum jumentorum (true Guinea grass)	4.37	2.51	16.51	7.77	10.18	14.16	35.93	8.57	.....	.....
Panicum obtusum	5.18	6.71	48.60	4.20	5.91	3.13	21.65	4.62	.....	.....
Panicum virgatum (tall panic grass)	5.50	3.56	51.17	4.93	7.87	3.63	18.76	3.36	.....	1.22
Panicum	4.37	5.29	45.10	4.06	7.39	7.98	22.53	1.54	.....	1.74
Panicum Texanum (Texas millet)	8.48	4.63	34.31	6.55	7.39	4.57	27.95	4.54	.....	1.58
Panicum Crusgalli (barn-yard grass)	4.27	3.69	42.18	11.48	7.23	5.52	13.26	12.00	.....	.37
Panicum filiforme (slender crab grass)	6.37	4.84	40.36	12.17	4.69	5.18	12.98	13.41	.....	.....
Sorghum halapense (Johnson grass)	10.44	2.96	22.21	4.58	12.87	6.73	35.72	3.68	.....	.81
Sorghum avenaceum (Indian grass)	2.35	2.13	61.56	6.11	2.92	1.36	16.84	6.74	.....	.....
Muhlenbergia diffusa (drop seed)	6.65	3.39	39.98	8.21	11.95	4.39	17.32	6.78	.....	1.33
Bromus unioloides (Schrader's grass)	8.79	5.61	4.84	16.84	4.43	4.64	37.20	16.38	.....	1.27
Bromus carinatus (broome grass)	9.29	3.94	38.33	3.30	6.19	2.19	31.61	.....	2.17	2.98
Agrostis exarata (brown top)	8.01	1.93	34.63	3.60	5.61	3.84	38.41	3.97	.....	.....
Paspalum lævе (water grass)	6.18	5.64	44.65	1.73	9.36	5.26	25.44	.....	.60	1.12
Setaria setosa (bristly foxtail)	3.24	3.51	42.59	3.81	2.31	1.56	39.33	.....	1.18	2.47
Leptochloa mucronata (feather grass)	6.46	3.31	55.92	2.89	5.94	2.66	20.21	1.81	.....	.80
Tripsacum dactyloides (gama grass)	2.52	3.69	37.84	13.08	1.64	1.07	29.06	6.30	.....	4.77
Tricurpis sesleroides (tall red top)	1.58	4.04	37.52	7.39	2.32	.53	38.49	8.13	.....	.....

CONCLUSION.

The work which has been collected in the previous pages extended over several years, from 1878 to 1883. It was inaugurated by Dr. Peter Collier, as chemist to this Department, and the laboratory work for the first year was in the hands of Mr. Henry B. Parsons, Mr. Charles Wellington, and myself. The remainder of the work has been under my own supervision, and has been almost entirely carried out by Mr. Miles Fuller and myself. It is hoped that the collection and rearrangement of the results will give them an increased value.

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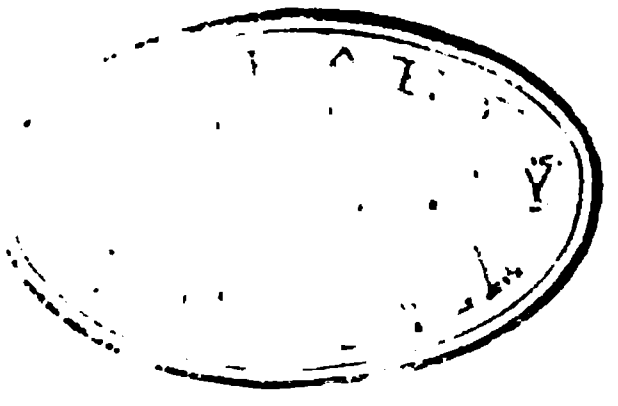

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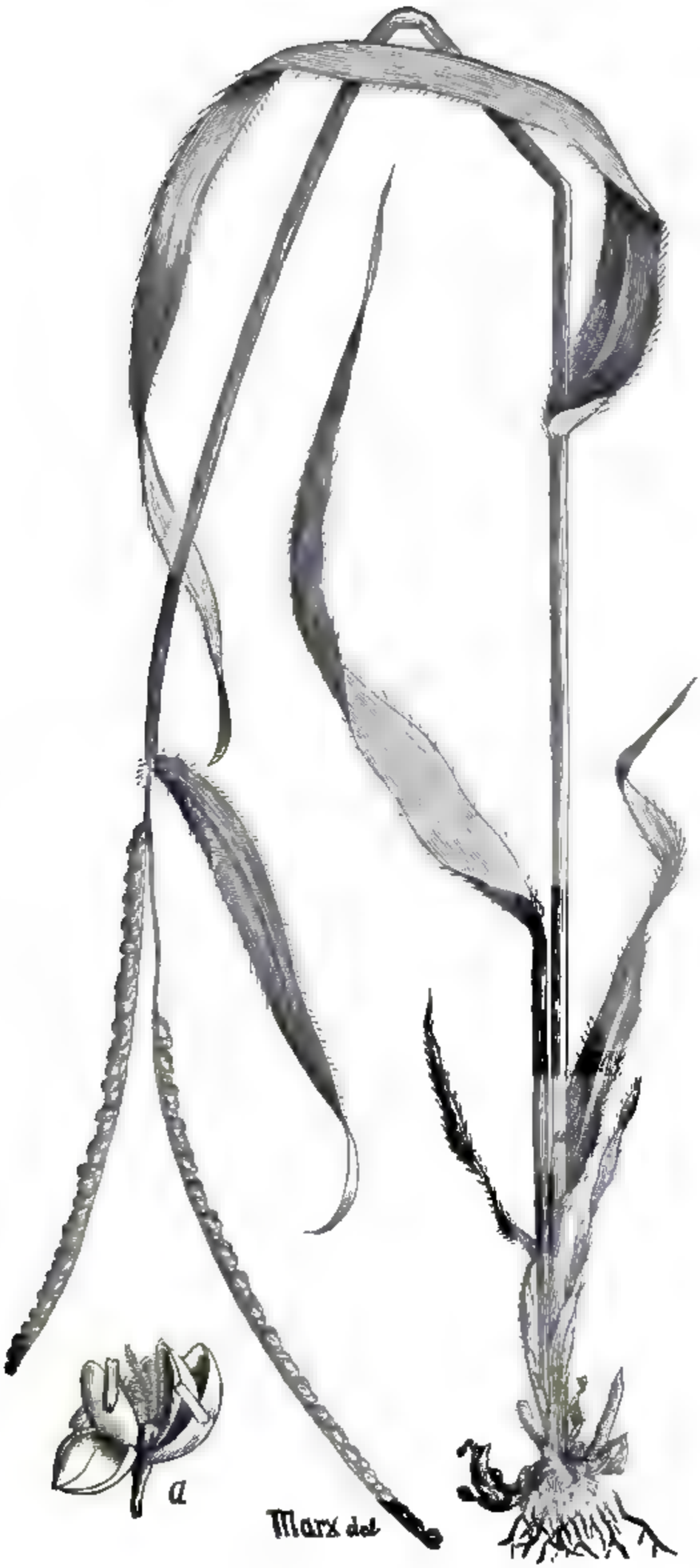
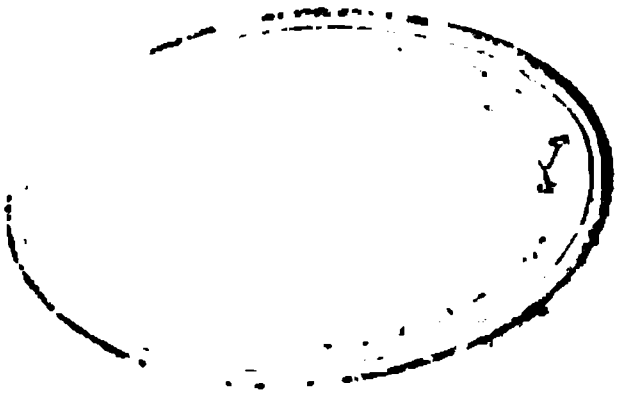


PASPALUM SETACEUM.

PANICUM SANGUINALE.

PANICUM JUMENTORUM.

PANICUM BARBINODE.



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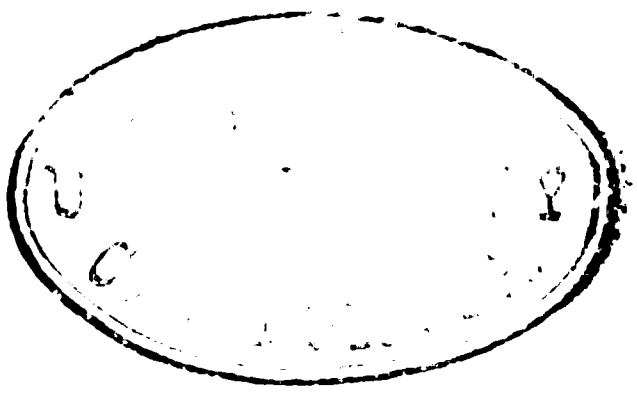

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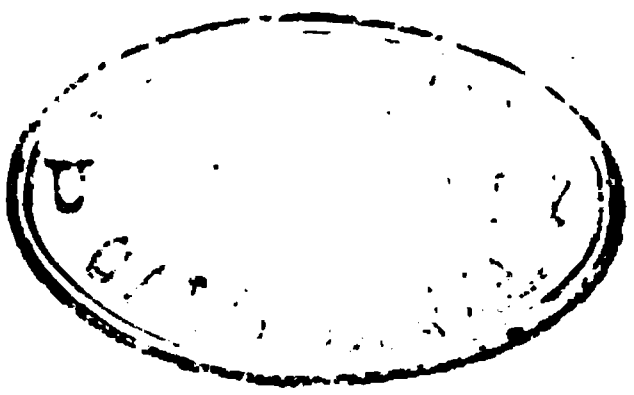
PANICUM AGROSTOIDES.



PANICUM ANCEPS.

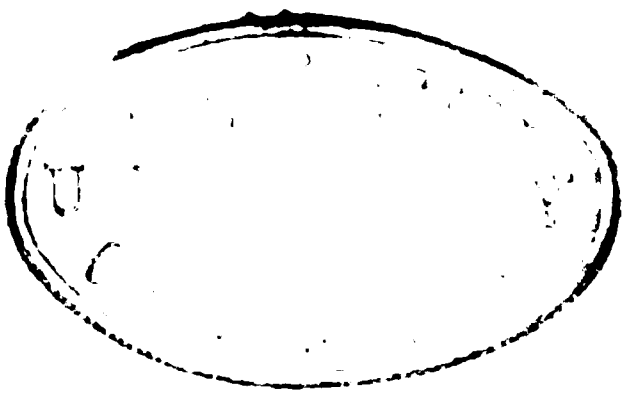
PANICUM CRUS-GALLI.

PANICUM VIRGATUM.

MARX DEL.

H.H.N.Sc.

PANICUM DIVARICATUM.



PANICUM GIBBUM.

PANICUM CAPILLARE.

Marx del.

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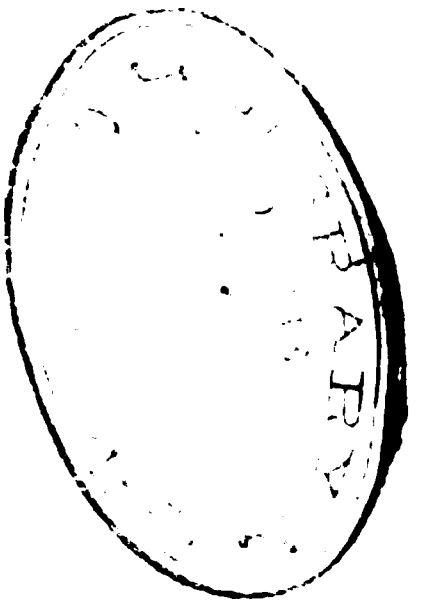
SETARIA SETOSA.

SHOLS—ENG

DEL.

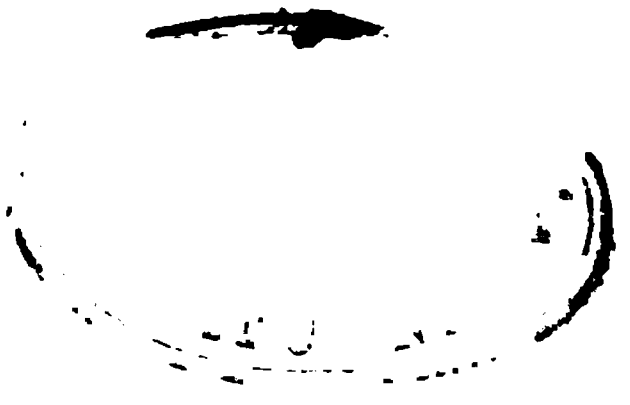
SETARIA GLAUCA.

SPARTINA CYNOSUROIDES.



SPARTINA JUNCEA.

TRIPSACUM DACTYLOIDES.



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HILARIA JAMESII.

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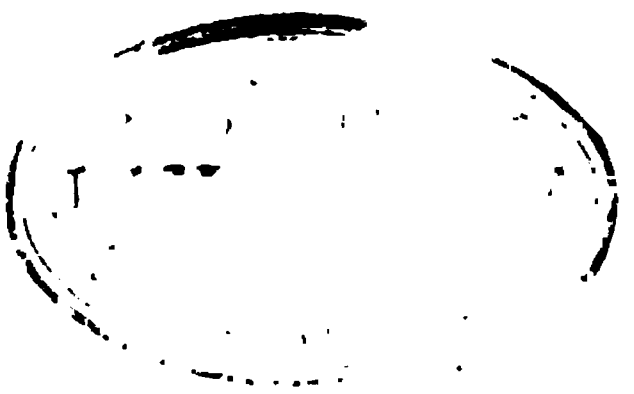
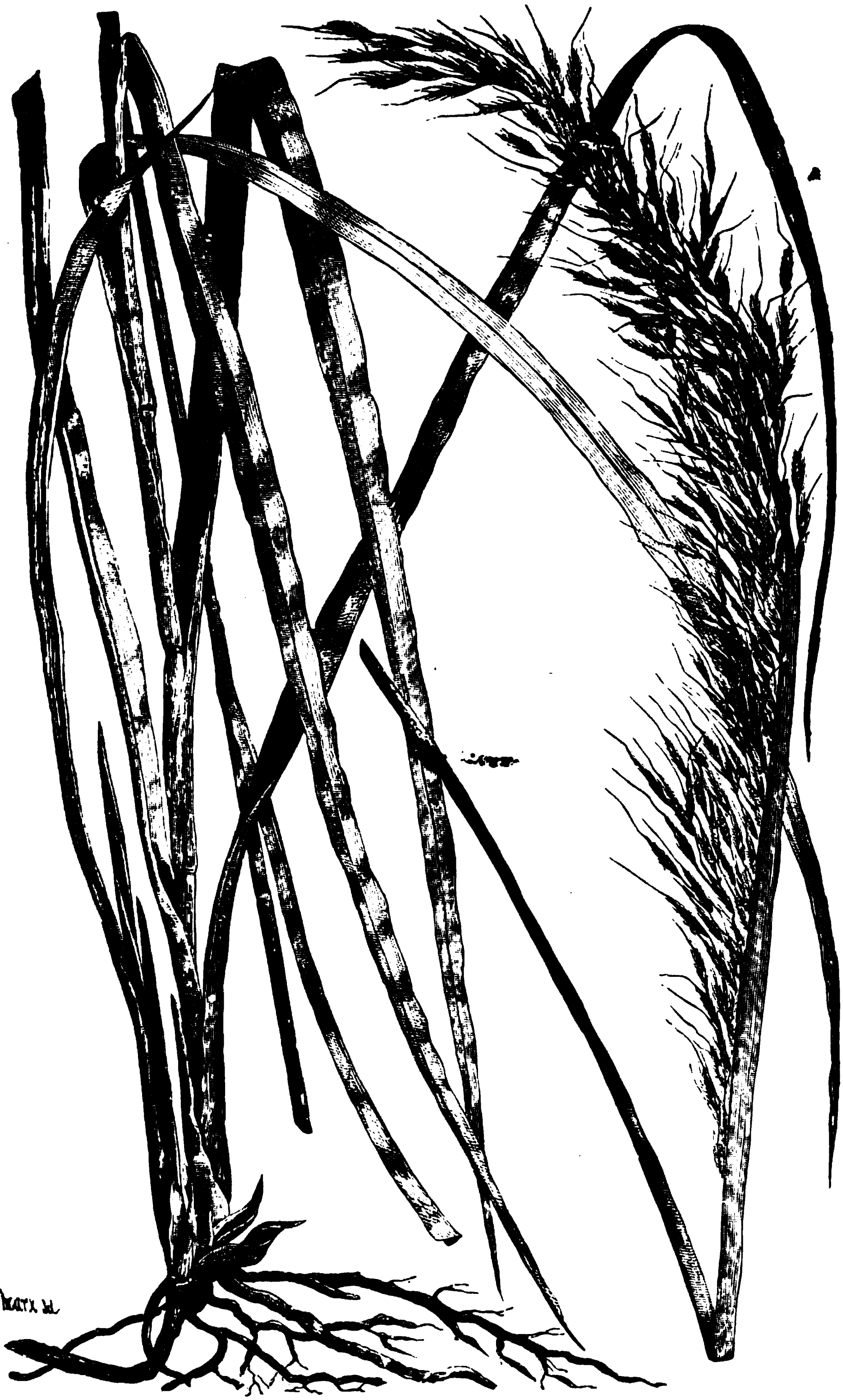


ANDROPOGON SCOPARIUS.

ANDROPOGON MACROURUS.

ANDROPOGON FURCATUS.



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SORGHUM HALAPENSE.

PHALARIS ARUNDINACEA.

H.H.NICHOLS. SC.

PHALARIS INTERMEDIA.

EL.

ANTHOXANTHUM ODORATUM.

HIEROCHLOA BOREALIS.

ALOPECURUS PRATENSIS

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NICHOLS-ENG.

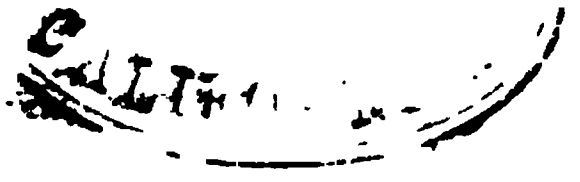
MARX.DEL.

ARISTIDA PURPUREA.

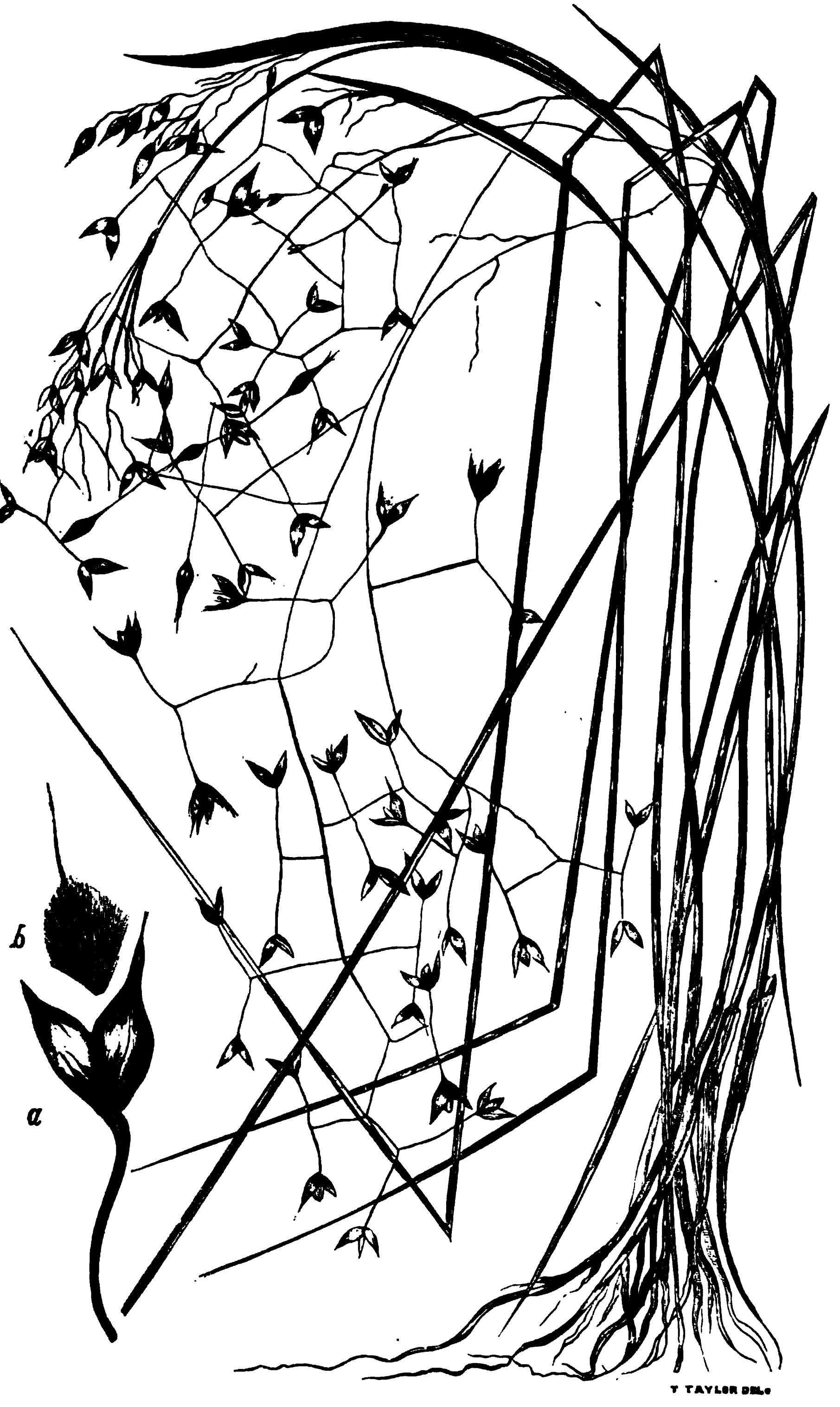
ARISTIDA BROMOIDES.

STIPA VIRIDULA.

STIPA SETIGERA.



STIPA EMINENS.



T TAYLOR DEL.

UC

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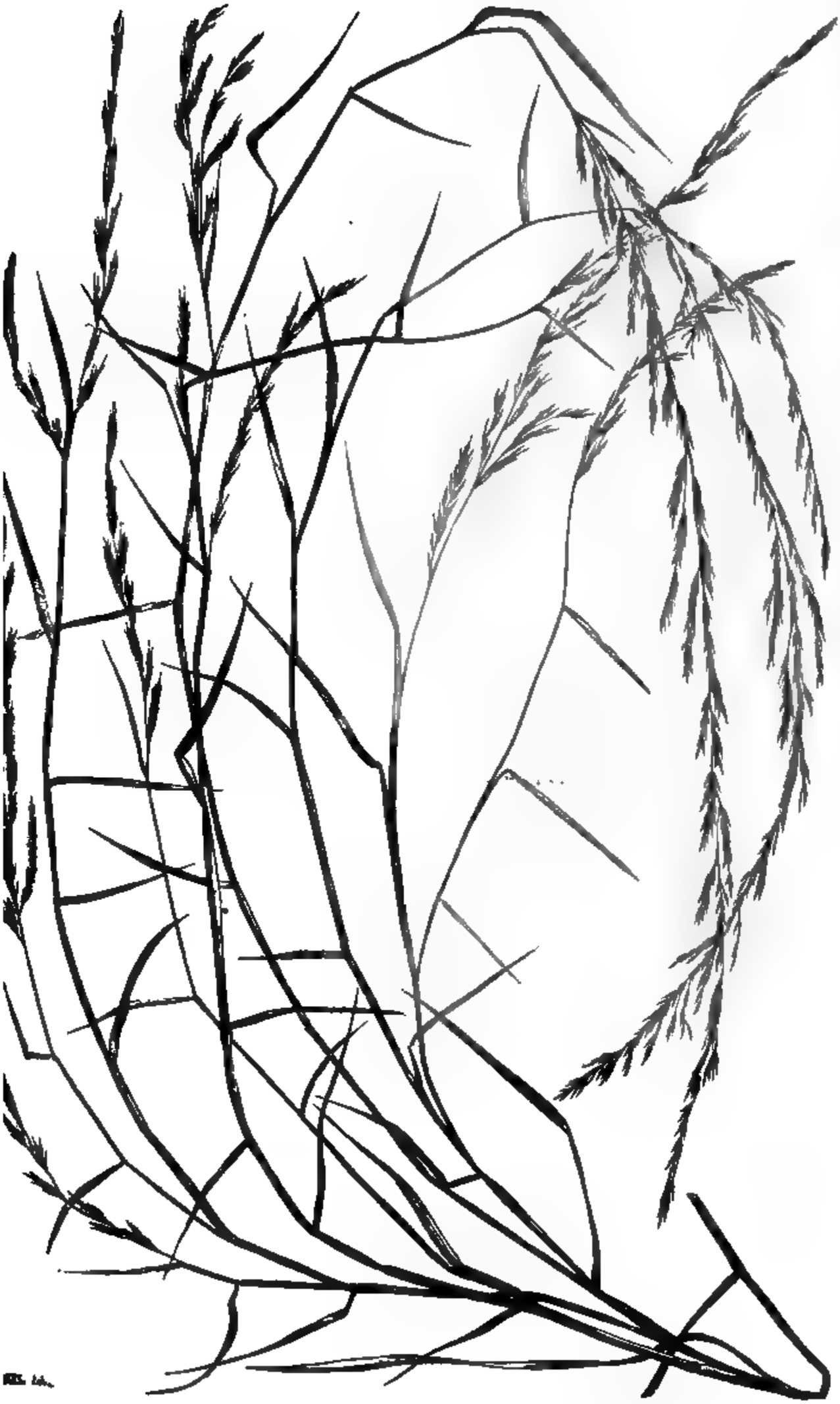
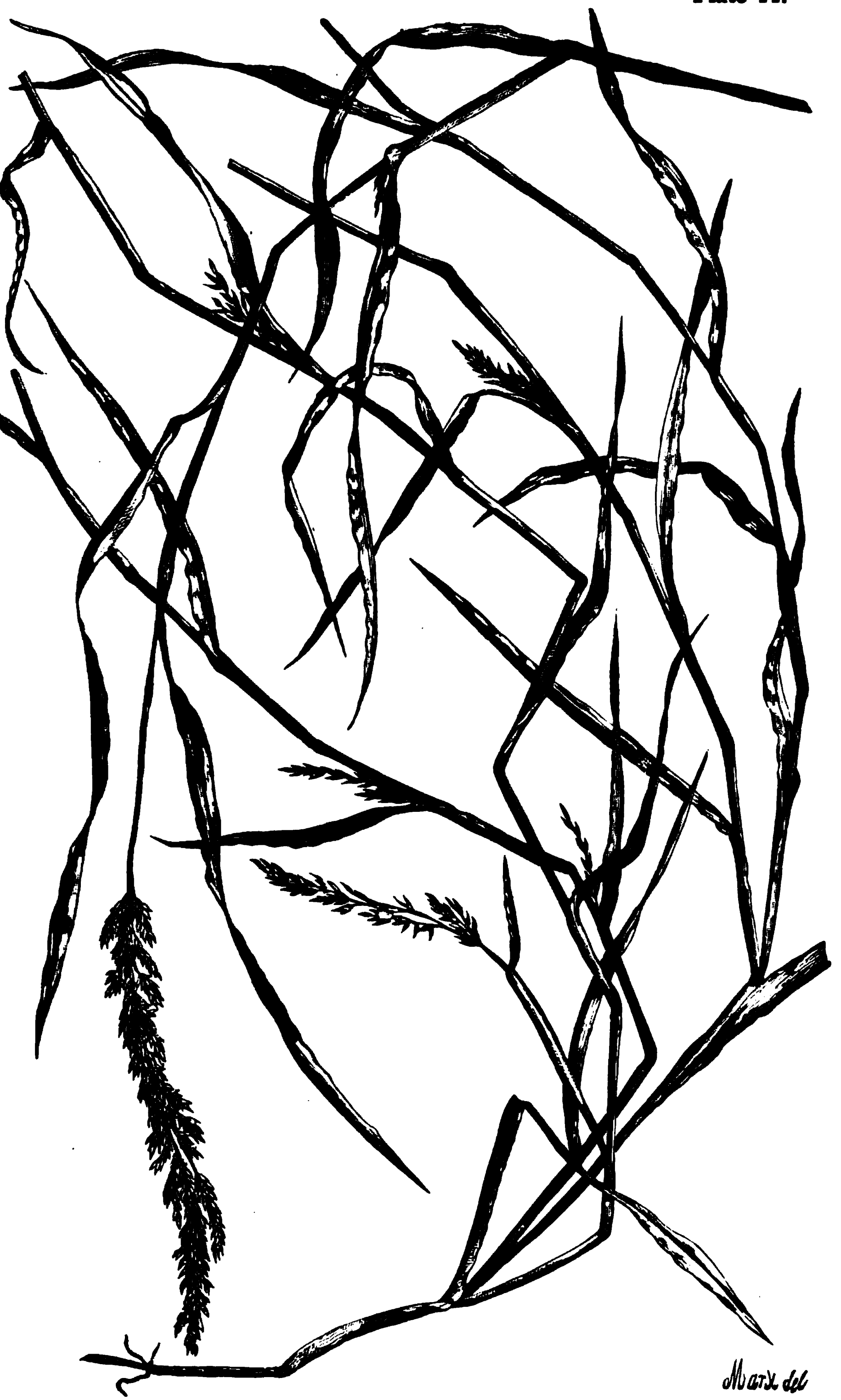
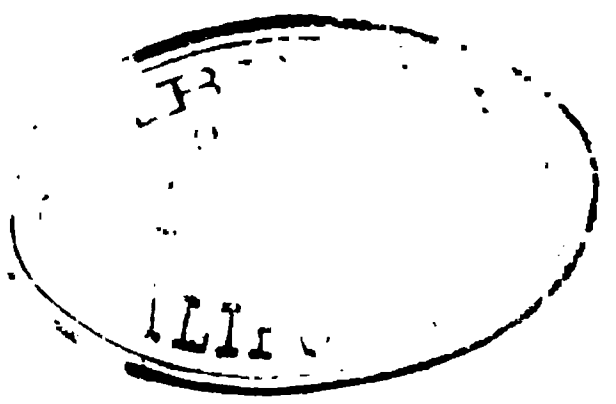


MUHLENBERGIA DIFFUSA.



MUHLENBERGIA MEXICANA.



MUHLENBERGIA SYLVATICA.

MUHLENBERGIA GLOMERATA.

MUHLENBERGIA COMATA.

MUHLENBERGIA GRACILIS.

PHLEUM PRATENSE.

Sporobolus Indicus.

SPOROBOLUS CRYPTANDRUS.

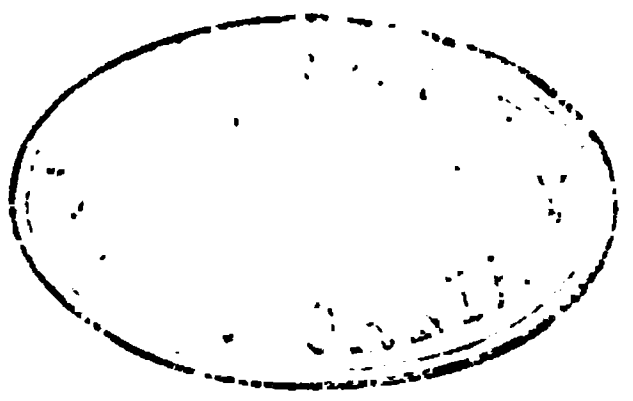
SPOROBOLUS AIROIDES.

AGROSTIS VULGARIS.

AGROSTIS EXARATA.

AGROSTIS EXARATA (var.).

AGROSTIS MICROPHYLLA.



ORNIA.

POLYPOGON MONSPELIENSIS.

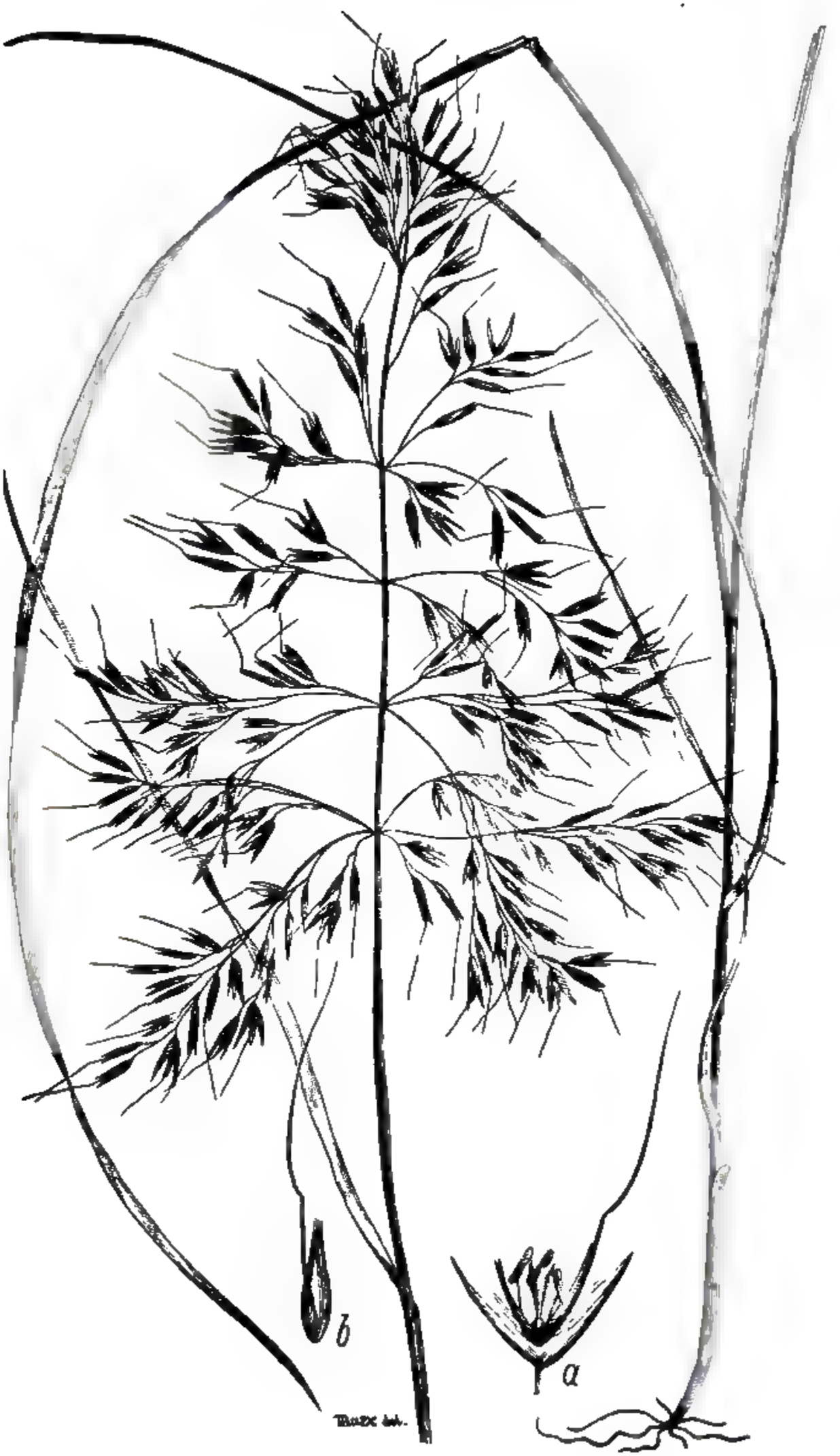
CINNA ARUNDINACEA

NICHOLS-ENG. MARSHALL.

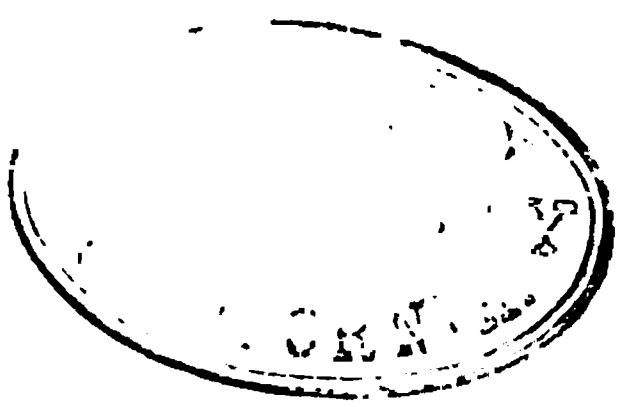
DEYEUXIA (CALAMAGROSTIS) CANADENSIS.

DEYEUXIA (CALAMAGROSTIS) SYLVATICA.

L FORNIA



DEYEUXIA HOWELLII.



DESCHAMPSIA AQUATICA CESPITOSA

ORNIA.

POLYPOGON MONSPELIENSIS.

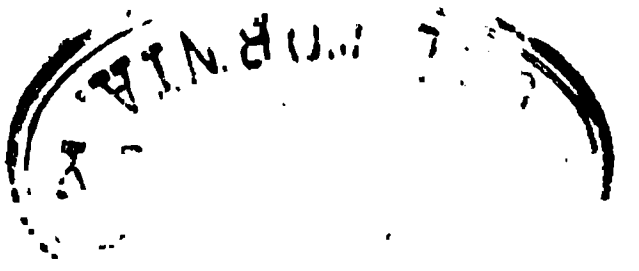
CINNA ARUNDINACEA.

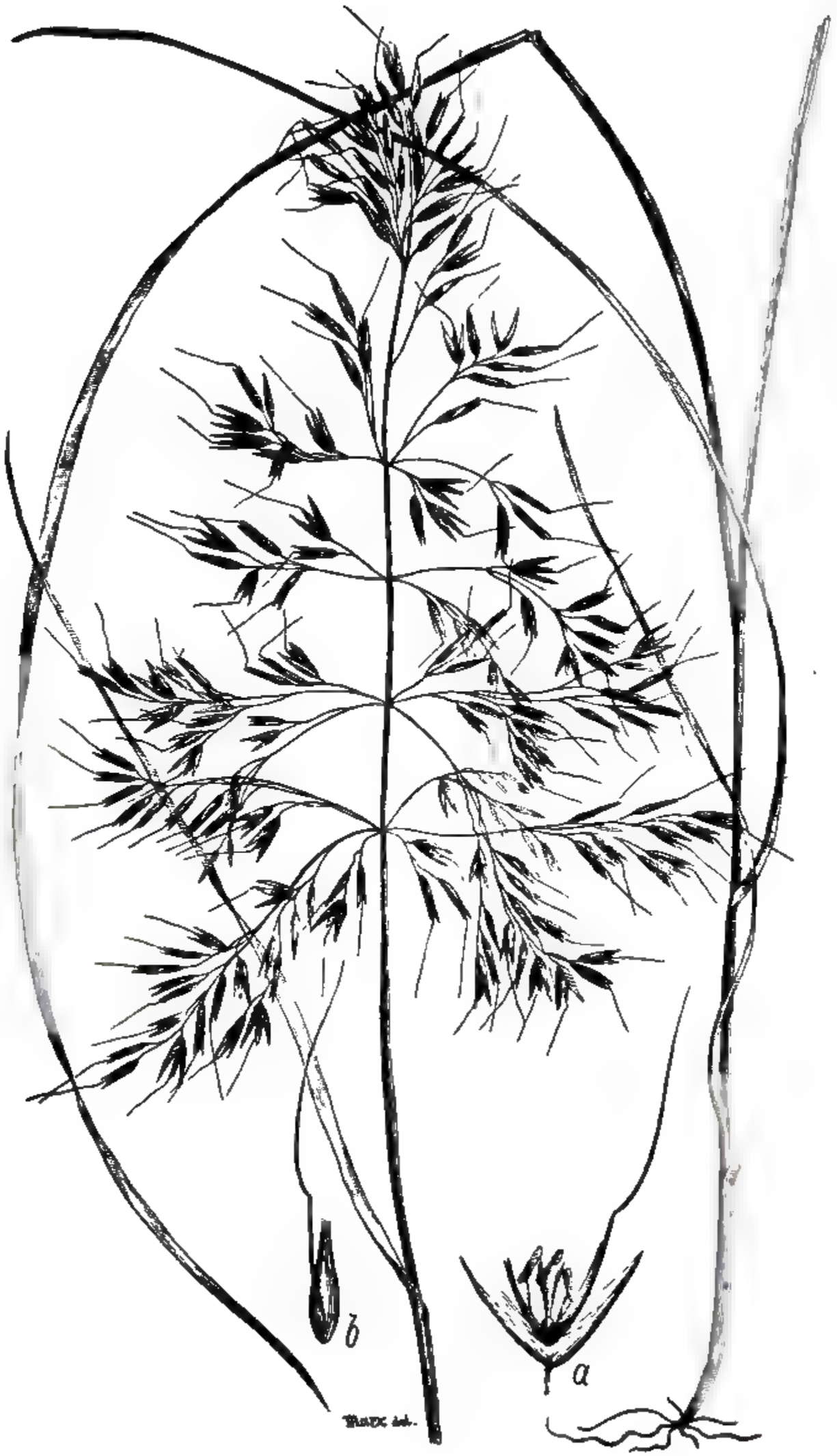
CALIFORNIA

NICHOLS-ENG.

Deyeuxia (Calamagrostis, Canadensis.

DEYEUXIA CALAMAGROSTIS SYLVATICA.





DEYEUXIA HOWELLII.

DESCHAMPSIA (AIRA) CÆSPITOSA.

Deschampsia (Aira) danthonioides.

HOLCUS LANATUS.

TRISETUM PALUSTRE.

TRISETUM CERNUUM.

TRISETUM SUBSPICATUM.

AVENA FATUA

AVENA STRIATA.

ARRHENATHERUM AVENACEUM.

U C

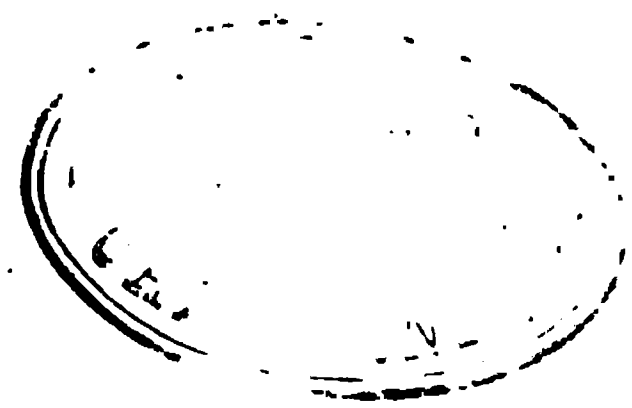
DANTHONIA SPICATA.

UC CALIFORNIA

DANTHONIA COMPRESSA.

DANTHONIA SERICEA.

c
b
a
a



CYNODON DACTYLON.

CHLORIS ALBA.

BOUTELOUA OLIGOSTACHYA.

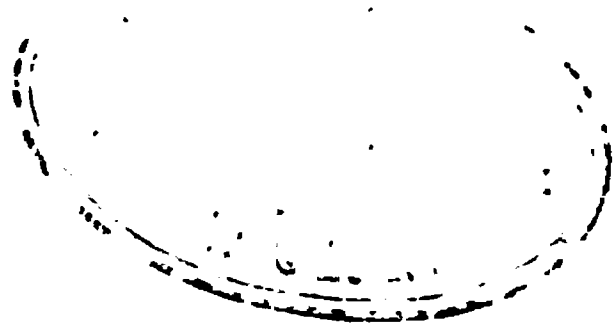
BOUTELONA POLYSTACHYA.

Eleusine Indica.

LEPTOCHLOA MUCRONATA.

BUCHLOE DACTYLOIDES.

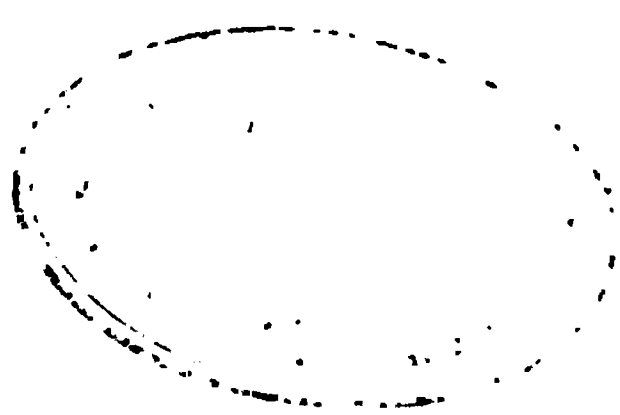
TRIODIA (TRICUSPIS) SESLERIOIDES.



TRIODIA TRINERVIGLUMIS.

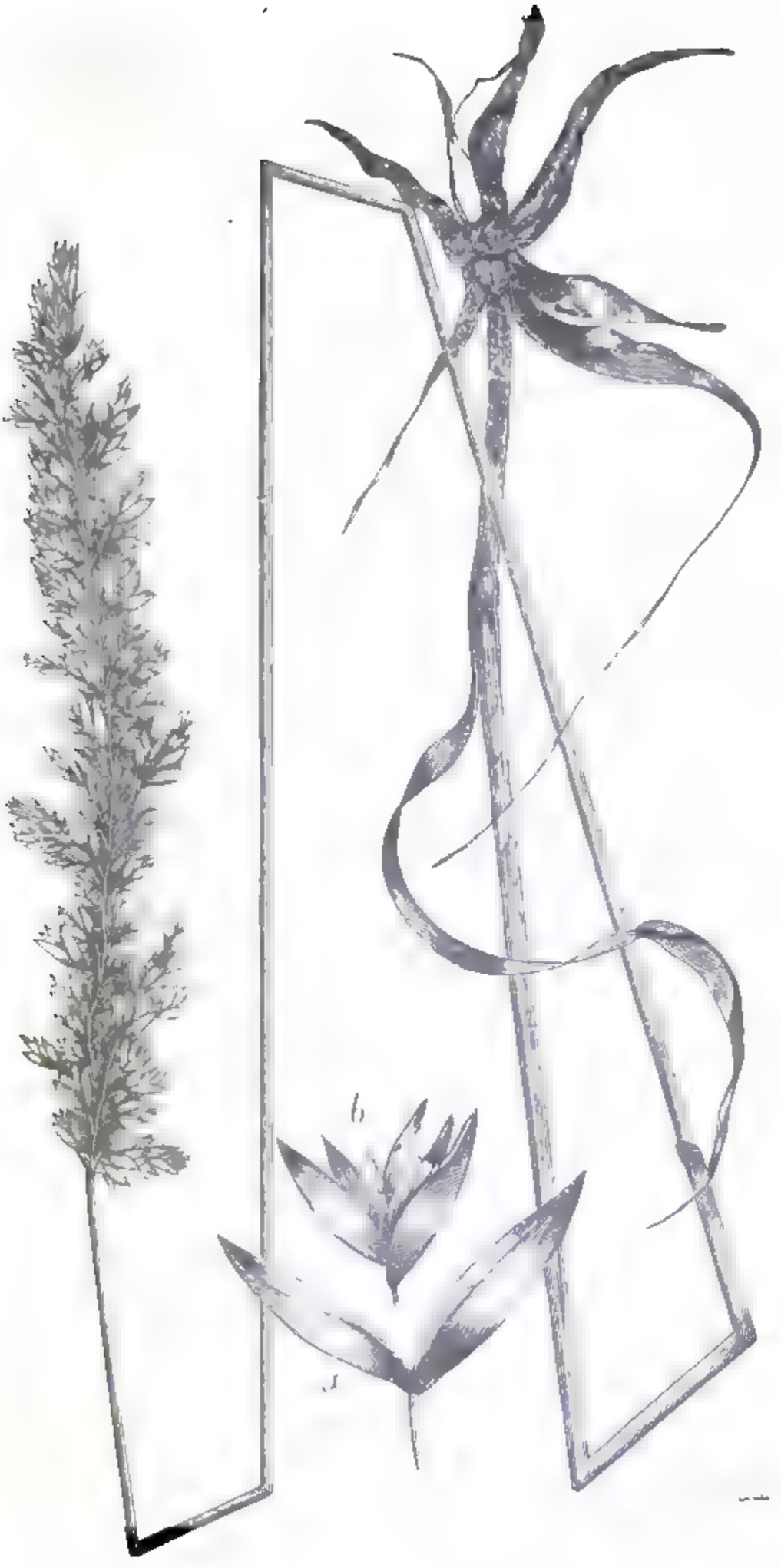
TRIODIA ACUMINATA.

DIPLACHNE FASCICULARIS.



DIPLACHNE DUBIA.

PHRAGMITES COMMUNIS.



KOELERIA CRISTATA.

ERAGROSTIS POLOIDES.

ERAGROSTIS PURSHII.

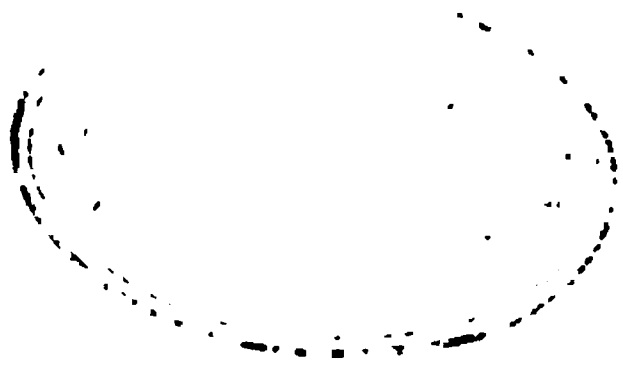
MELICA MUTICA, var. DIFFUSA.

N.H.NICHOLS.

T.TAYLOR.DEL.

MELICA BULBOSA.

MELICA IMPERFECTA.



Uniola latifolia.

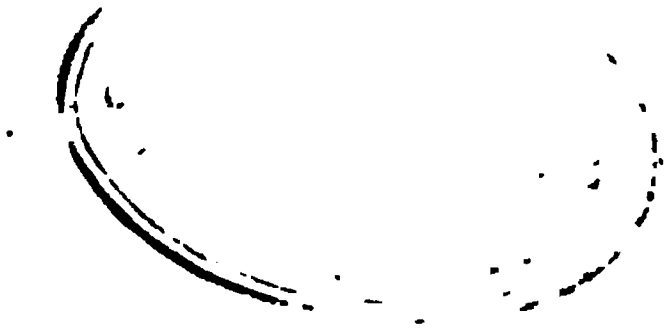
DISTICHLIS MARITIMA.

Dactylis glomerata.

POA PRATENSIS.

Poa serotina.

Poa compressa.

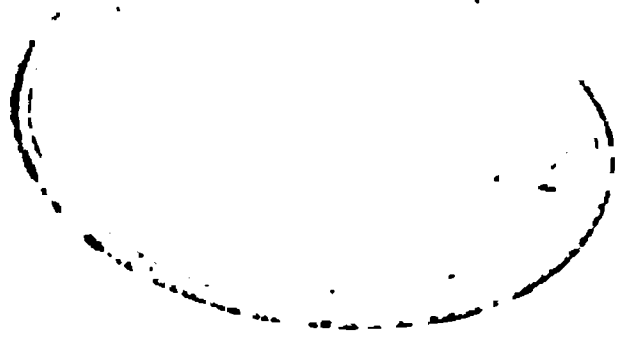


POA ARACHNIFERA.

POA TENUIFOLIA (var.).

Poa tenuifolia (var.).

Poa alsodes.



POA ANDINA (of Nuttall).

GLYCERIA AQUATICA.

GLYCERIA NERVATA.

GLYCERIA CANADENSIS.

FESTUCA ELATIOR.

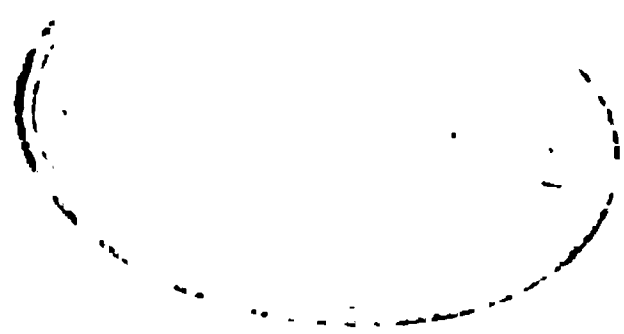
Plate 108.

FESTUCA OVINA.

FESTUCA MICROSTACHYS.

Festuca scabrella.

Bromus secalinus.



Bromus unioloides ($\frac{1}{2}$ size).

BROMUS ERECTUS.

LOLIUM PERENNE.

AGROPYRUM (TRITICUM) REPENS.

Plate 111.

BROMUS SECALINUS.

Bromus unioloides ($\frac{1}{2}$ size).

BROMUS ERECTUS.

LOLIUM PERENNE.

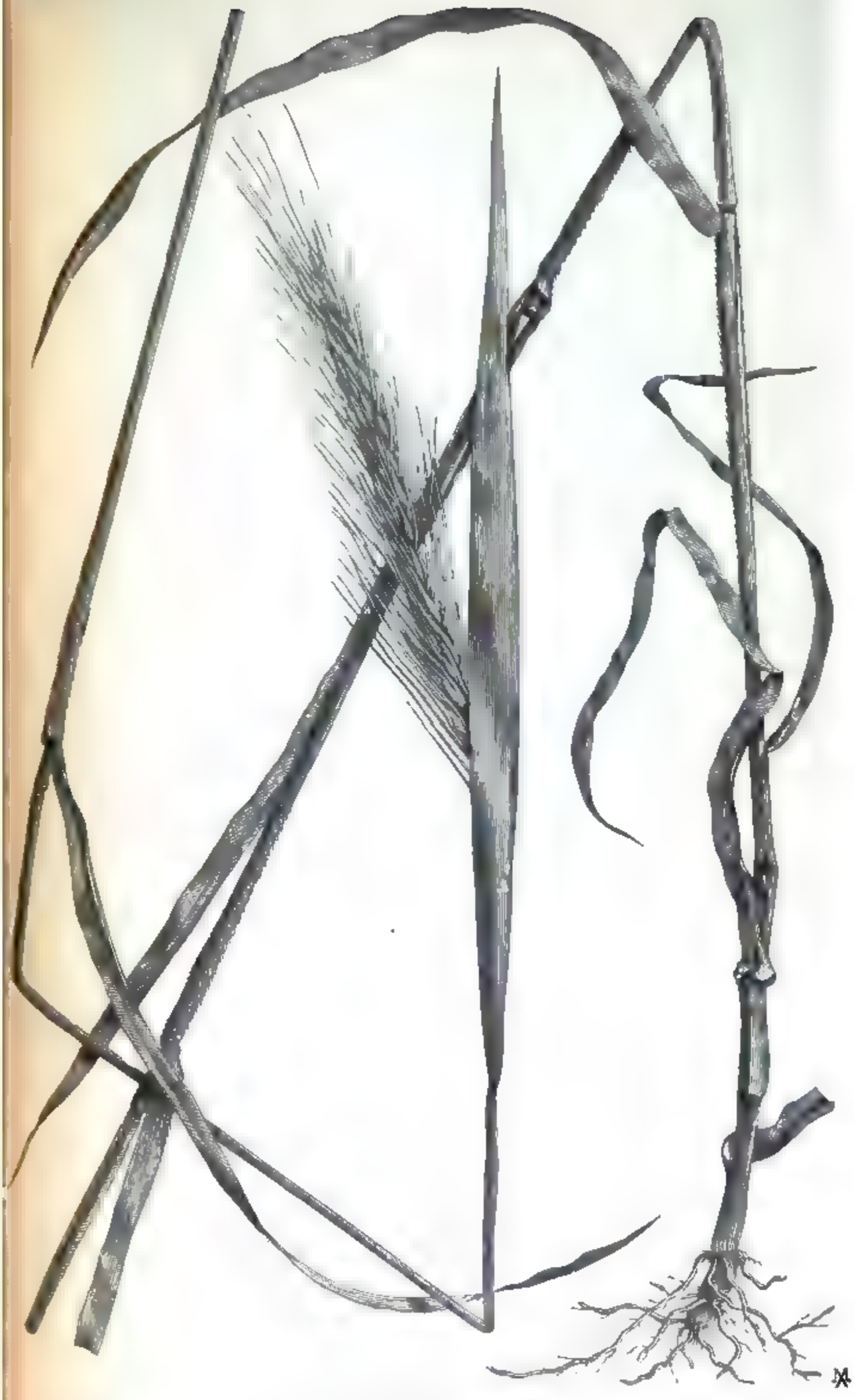
AGROPYRUM (TRITICUM) REPENS.

HORDEUM NODOSUM.

ELYMUS CANADENSIS.

MARX.DEL

ELYMUS VIRGINICUS.



ELYMUS STRIATUS.

ELYMUS CONDENSATUS.

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